Fish Populations of Mammoth Creek
Mono County, California (1988 – 2007)

Prepared for:
Mammoth Community Water District
P.O. Box 597
Mammoth Lakes, CA 93546

Prepared by:
HDR|SWRI
1610 Arden Way, Suite 175
Sacramento, CA 95815

December 2007

Fish Populations of Mammoth Creek
Mono County, California (1988 – 2007)

Prepared by:

Paul. M. Bratovich, M.S.
Jose Perez-Comas, Ph.D.
Adrian Pitts, B.S.

HDR|SWRI
1610 Arden Way, Suite 175
Sacramento, CA 95815

December 2007

ACKNOWLEDGEMENTS

We acknowledge and thank the authors of the 16 annual fish community survey reports conducted since 1988 including: Bratovich *et al.* 1990; Hood *et al.* 1992, 1993, 1994; Jenkins and Dawson 1996, 1997; Hood 1998; Jenkins 1999; Hood 2001, 2002, 2003, 2004, 2006a, 2006b; and in particular Salamunovich (2006, 2007), who provided very useful, updated information on Mammoth Creek and its fish communities. Special thanks are extended to Mammoth Community Water District and its General Manager, Mr. Gary Sisson.

Fish Populations of Mammoth Creek
Mono County, California (1988 – 2007)

TABLE OF CONTENTS

Fish Populations of Mammoth Creek
Mono County, California (1988 – 2007)

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

Figure **Page**

LIST OF FIGURES (cont.)

LIST OF TABLES

Table **Page**

LIST OF APPENDICES

Fish Populations of Mammoth Creek, Mono County, California (1988 – 2007)

1.0 INTRODUCTION

Instream flow needs for the fish populations in Mammoth Creek, Mono County, California have been the focus of several investigations since the 1970's. As a result of these investigations, various bypass flow schedules have been developed for the purpose of sustaining the aquatic habitat and fishery resources in Mammoth Creek.

The objectives of this report are to summarize the results of the fisheries investigations that have been conducted since 1988, examine potential temporal trends in abundance, and evaluate potential relationships between fish population abundance and flows in Mammoth Creek.

2.0 REGIONAL SETTING/BACKGROUND

Mammoth Creek originates high in the southern Sierra Nevada, and is one of several creeks that flow into the Mammoth Lakes Basin. The Mammoth Lakes Basin is a popular outdoor recreation area located in Mono County, California, ranging in elevation from about 11,000 feet in the headwaters along the Mammoth Crest to about 7,000 feet at the confluence of Mammoth and Hot creeks, with a drainage area of about 71 square miles (DWR 1973).

Mammoth Creek drains the Mammoth Lakes Basin, flows through the Town of Mammoth Lakes, and discharges into Hot Creek (**Figure 1**). Mammoth Creek is part of the Owens Subprovince of the Great Basin Province (Moyle 2002). Historically, trout are believed to have not been present in the Owens River watershed, including the Mammoth Lakes Basin. Moyle *et al.* (1996) suggested that native fishes in the Owens River Basin, with the exception of the Owens sucker, generally did not occur in streams above 4,900 feet in elevation. Fishes native to the regional setting include Owens sucker (*Catostomus fumeiventris*) and Owens tui chub (*Gila bicolor snyderi*), both of which are presently found in the lower reaches of Mammoth Creek.

Presently, Mammoth Creek supports brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) along much of its length. It is unknown when rainbow trout were introduced into the Mammoth Lakes Basin, but Jenkins *et al.* (1999) suggested that brown trout were probably introduced into the basin in the 1870's. In the past, the California Department of Fish and Game (CDFG) planted brown trout from the Hot Creek Hatchery into Mammoth Creek, although brown trout have not been planted in the creek since 1982. Naturalized populations of rainbow trout and brown trout presently occur in Mammoth Creek. The CDFG also annually planted rainbow trout from the Hot Creek Hatchery into Mammoth Creek until 2007, and has recently shifted the planting of rainbow trout into Mammoth Creek to stocks from the Mount Whitney Hatchery.

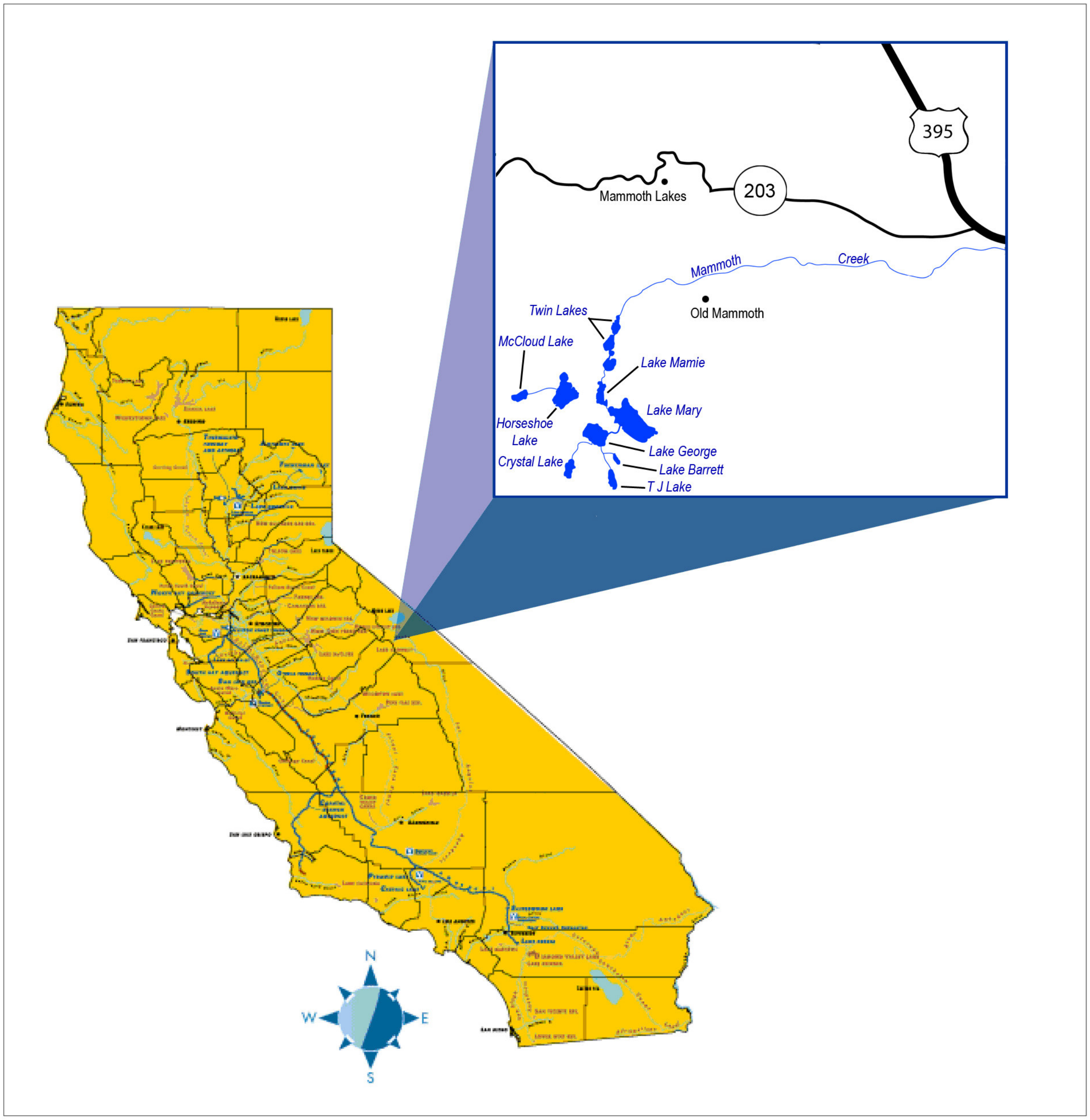

Figure 1. Mammoth Creek, Mono County, California.

3.0 EXPERIMENTAL DESIGN AND SAMPLING

Extensive evaluations of Mammoth Creek and its fish resources were initiated in 1988. The experimental design and rationale for the original selection of the fish survey sample sites are described in Bratovich *et al.* (1990). They established the Mammoth Creek study area as extending from Lake Mary downstream to the confluence of Mammoth Creek and Hot Creek, a distance of approximately 10.4 miles. Five distinct reaches were identified in Mammoth Creek, based upon analysis of topographic maps, calculation of gradient profiles, and visual inspection of the creek and associated morphological characteristics, tributaries, riparian vegetation and surrounding topography. Four of these reaches were located in the lower 8.9 miles (86.3 percent of the entire length) of the creek, and were characterized by gradients that range from 0.7 to 3.8 percent. By contrast, a fifth reach comprised of the upper 1.4 miles (13.7 percent of the creek) was characterized by a gradient of approximately 12.3 percent. Habitat in this high-gradient reach (Reach A) typically consisted of a cascade-plunge pool sequence in which the amount of usable fish habitat was not determined by stream discharge, but by sectional (streambed rock) hydraulic controls. Habitat characterization and all subsequent investigations, including fish surveys, were restricted to the remaining four study reaches (Reaches B, C, D, E). Thus, the fish survey project area consists of the lower 8.9 miles of Mammoth Creek from the Sherwin Street crossing in the Town of Mammoth Lakes downstream to Mammoth Creek's confluence with Hot Creek.

Aquatic habitat characteristics vary considerably among the four study reaches based upon the combination of channel morphology, riparian vegetation, stream gradient, and bed substrate size and composition. Channel braiding occurs in each study reach and apparently resulted from large woody debris accumulation in lower gradients sections of the channel (Bratovich *et al.* 1990).

Distinct differences in the amounts of riparian cover within each study reach were observed during the habitat mapping survey conducted in 1988 (Bratovich *et al.* 1990). To ensure representation of riparian cover and dispersion of sampling sections, fish sampling stations were originally located within "high" and "low" density riparian habitat sites within each study reach. Each sampling site was identified by a two-letter code, with the first letter indicating the reach (B, C, D, or E) and the second letter indicating a "high" (H) or "low" (L) density riparian characterization.

Fish community surveys were conducted with a relatively consistent sampling methodology in 1988, 1992 through 1997, and 1999 through 2007. Several entities have been involved in the collection and reporting, including Beak Consultants in 1988 and 1992-1994, UC SNARL in 1995 and 1996, Thomas Jenkins in 1999, KDH in 1997 and 2000-2005, and Thomas R. Payne and Associates in 2006 and 2007.

The data used in this report were obtained from the fish community surveys performed in Mammoth Creek in 1988, 1992-1997 and 1999-2007. During these fish community surveys four contiguous reaches (i.e., Reaches B through E) were sampled **(Figure 2)**. Each surveyed reach contained two randomly located sampling sites that were approximately 300-ft long[1], one catalogued as having high riparian cover (i.e., H), and the other as having low riparian cover (i.e., L). **Table 1** displays the limits, length and number of potential sample sites per reach, and the number of H and L sites electrofished each year.

During the 16 annual fall surveys, fish were collected at each sampling site by electrofishing with a multiple-pass removal method. Three complete passes were normally conducted at each sampling site. Prior to electrofishing, the upstream and downstream boundaries of selected sampling sites were identified with rebar driven into each bank. On the day of sampling, sites

[1] During the 1988 survey the electrofishing sites were approximately 100-ft long instead of 300-ft long. Except for the 2006 surveys, the exact lengths of the annually sampled sites were not reported. In 2006, the length of the eight sampled sites averaged 299.6 ft with a standard error of 12.3 ft.

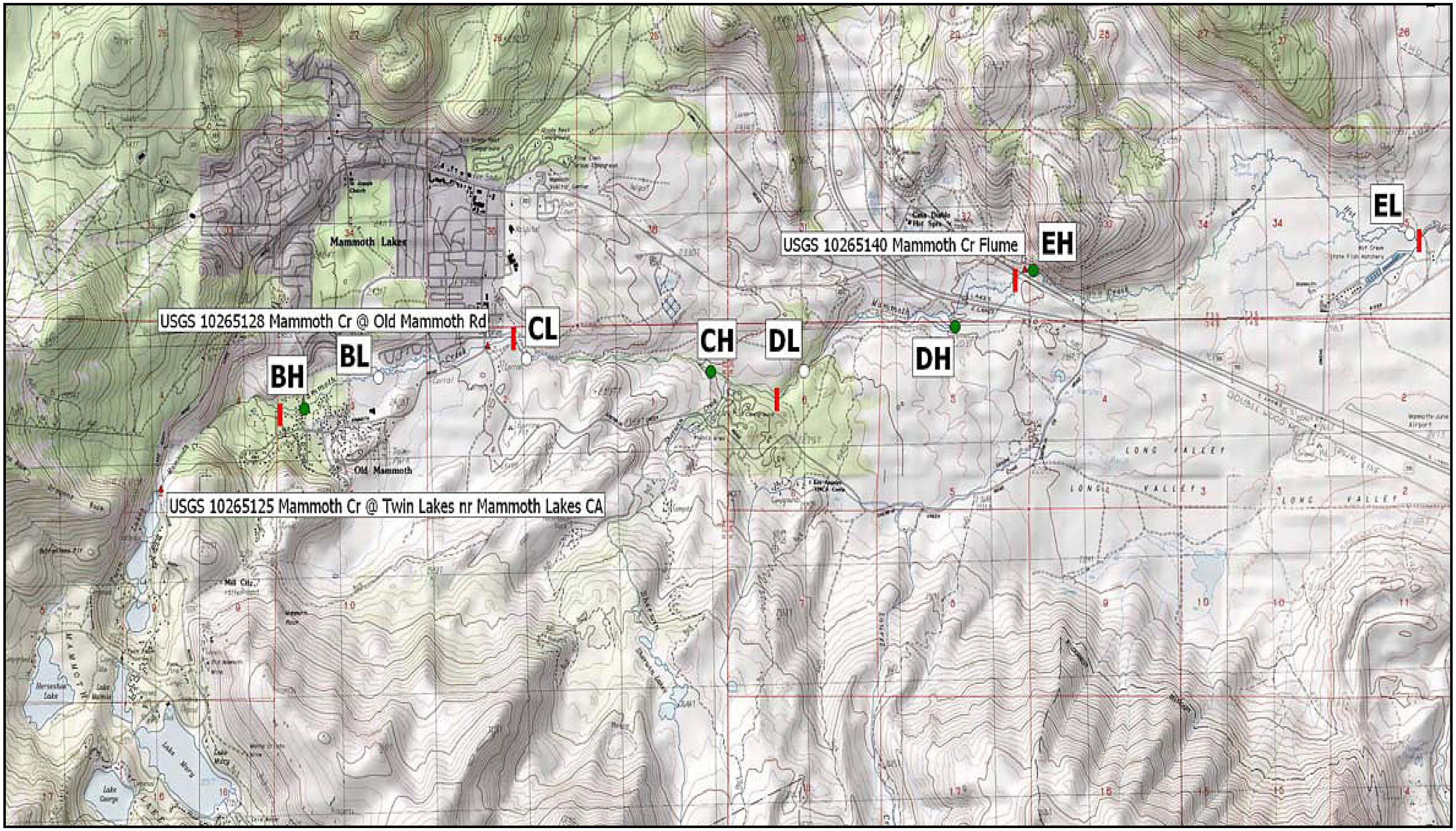

Figure 2. The Mammoth Creek basin and location of the eight fish sampling sites. Red hashes indicate reach boundaries. Green dots represent high riparian density fish samples sites, white dots represent low riparian density sites. Red triangles identify stream flow gage locations.

Table 1. Mammoth Creek fish community survey sample site characteristics.

Reach	B		C		D		E		Total	
Upstream Reach Limit	Sherwin St.		Canyon head		Sherwin Creek footbridge		Hwy 395 bridge		Sherwin St.	
Downstream Reach Limit	Canyon head		Sherwin Creek footbridge		Hwy 395 bridge		Hot Creek		Hot Creek	
Reach Length (ft)	9,842		8,661		9,055		19,685		47,243	
1988 Sampling Site Length (ft)	100		100		100		100		100	
1992-2005 Sampling Site Lengths (ft)	300		300		300		300		300	
Measured 2006 and 2007 Sampling Site Lengths (ft)	303	287	300	309	320	294	281	303	301	298
1988 Sampling Sites (N)	98		87		91		197		473	
Potential 1992-2007 Sampling Sites (N)	33		29		30		66		158	
Sites Annually Sampled per Reach Riparian Category	H	L	H	L	H	L	H	L	H	L
Nov. 2-4, 1988	1	1	1	1	1	1	1	1	4	4
Oct. 21-28, 1992	1	1	1	1	1	1	1	1	4	4
Oct. 12-19, 1993	1	1	1	1	1	1	1	1	4	4
Oct. 4-11, 1994	1	1	1	1	1	1	1	1	4	4
Nov. 1-7, 1995	1	1	1	1	1	1	1	1	4	4
Oct. 3-8, 1996	1	1	1	1	1	1	1	1	4	4
Oct. 4-10, 1997	1	1	1	1	1	1	1	1	4	4
Sep. 24-29, 1999	1	1	1	1	1	1	1	1	4	4
Oct. 10-15, 2000	1	1	1	1	1	1	1	1	4	4
Oct. 9-13, 2001	1	1	1	1	1	1	1	1	4	4
Sep. 30 - Oct. 3, 2002	1	1	1	1	1	1	1	1	4	4
Sep. 29 - Oct. 3, 2003	1	1	1	1	1	1	1	1	4	4
Oct. 4-8, 2004	1	1	1	1	1	1	1	1	4	4
Sep. 30 - Oct. 5, 2005	1	1	1	1	1	1	1	1	4	4
Oct. 11 -15, 2006	1	1	1	1	1	1	1	1	4	4
Oct. 10 -14, 2007	1	1	1	1	1	1	1	1	4	4

were closed using 0.25-inch mesh block nets placed simultaneously across the upstream and downstream boundaries, using the rebar as anchors. A good description of field sampling methodologies is provided in Salamunovich (2006).

Over the years, several of the sample sites have been moved up or downstream due to changes in landowner access or channel morphology, although the habitat areas have remained unchanged (Hood 2006b). In the 2006 survey, the sites sampled were identical to those sampled in October

2007, and were easily identified by flagging and rebar left behind from previous surveys (Salamunovich 2006). Although sample site locations have remained relatively consistent, riparian cover has changed since establishment of the sample sites in 1988. In addition, the relative density characterization of "high" or "low" varies among reaches. For example, KDH in their 1997, 2000 and 2004 Mammoth Creek Fish Community Survey reports mention that "*site EH represents a zone of high riparian cover within reach E*" but "*in comparison with other high riparian cover sites, it is characterized by a relatively low amount of riparian cover*", and "*site DL was randomly selected within a low riparian zone for reach D but in fact has a high amount of willow cover*". KDH also mentioned that site BL has changed over time by willow tree cover establishments, resulting in increased riparian cover.

Salamunovich (2006) correctly states that … "*Discretion must be used when comparing and interpreting the results between high and low-density riparian cover sites because of between reach variation in riparian density and tree species and changes in the riparian area over time.*" Appropriately, the high and low riparian cover categories were not utilized as strata in the inter-annual trend analyses presented in this report because of among-reach differences in the relative amount of riparian cover required for a site to be classified as high or low cover, and because of site-specific changes in the amount of riparian cover over time.

The 16 annual surveys have shown that the species composition at Mammoth Creek consists primarily of brown trout (*Salmo trutta*), an introduced species that is now naturally reproducing in the creek and that, year-after-year, has generally represented at least 50 percent of the catch collected in the annual electrofishing surveys. Rainbow trout (*Oncorhynchus mykiss*) is the second most abundant salmonid species in Mammoth Creek, but its numbers rarely exceed 30 percent of the catch collected in the annual electrofishing surveys. This species is represented by naturally reproducing descendants from hatchery rainbow trout planted in past years, as well as by hatchery rainbow trout planted during each survey year. Numbers of other salmonids such as brook trout (*Salvelinus fontinalis*) are rare. The most common non-salmonid species present in the creek are tui chub (*Gila bicolor*) and Owens sucker (*Catostomus fumeiventris*).

4.0 DATA ANALYSIS

4.1 STANDARDIZED FISH ABUNDANCE

The population estimates and sample site lengths were used to extrapolate the population numbers to indices of fish abundance, expressed as the number of fish per mile in Mammoth Creek. The standardized abundance estimates (trout/mile) were calculated for both brown and "wild" rainbow trout for each of the sample sites for each of the 15 years included in the analysis. Average standardized estimates for both brown and "wild" rainbow trout were calculated annually, and for the overall 16-year period.

4.2 TROUT LENGTH-FREQUENCY

Fork lengths of "wild" and hatchery rainbow trout collected in Mammoth Creek were examined as reported by the various investigators over the 16-year period of record. For brown trout, the fork lengths of all brown trout captured over the 16-year period of record were used to determine the upper fork length limit for young-of-the-year (YOY). The fork lengths (mm) of all brown trout caught through electrofishing in each reach over the 16 annual surveys were used to construct histograms with 1-cm bins (**Figure 3**). Inspection of these histograms indicates that the upper fork length limit for YOY brown trout was 119 mm. Consequently, the annual brown trout survey data were revisited to separate all brown trout with fork lengths less than 120 mm. The resulting data subsets were considered YOY brown trout, and used to estimate their abundance and variance per sample site each year, with the aid of *Microfish 3.0* (**Table 2**).

4.3 INTER-ANNUAL ABUNDANCE TRENDS

The examination of rainbow trout temporal (inter-annual) trends and potential relationships between abundance and flows in Mammoth Creek is problematic for several reasons. First, physiologic characteristics such as frayed fins, deformed fins, missing adipose fins, or abraded skin on snouts or backs are not consistently reliable determinators of hatchery origin, and classifying fish as "wild" if they do not display those physiologic characteristics, also may not be accurate. Also, several different investigators (and field crews) have conducted the annual surveys over the years, and it is not possible to evaluate the consistency of visual physiologic examination and application for hatchery origin determination.

Second, the planting of rainbow trout by the California Department of Fish and Game into Mammoth Creek to support a recreational "put-and-take" fishery confounds the ability to examine inter-annual trends and potential relationships between abundance and flow. In past years, the location, timing and number of rainbow trout planted in Mammoth Creek annually are not readily discernable. In recent years (2004–2006), the number of rainbow trout planted in Mammoth Creek has ranged from an estimated 12,426 to 14,583 fish annually, at 12 to 15 different locations along the creek, about once a week throughout the April-October trout fishing season (**Table 3**) (Salamunovich 2006). Plantings of rainbow trout in Mammoth Creek have actually occurred when the annual fish surveys were being conducted (Salamunovich 2006).

Finally, the ability to restrict inter-annual trend analysis and evaluation of potential relationships between annual population estimates and flow to YOY rainbow (and brown) trout was examined. Restricting these further analyses to YOY trout has two major advantages. First, using YOY rainbow trout could provide opportunities to evaluate trends in the "wild" population, because CDFG plants much larger-sized, catchable rainbow trout for the "put-and-take" recreational fishing in Mammoth Creek. Thus, YOY rainbow trout would be a more reliable indicator of "wild" populations. Second, restricting inter-annual analysis to YOY trout populations also reduces the confounding influence of angling pressure and harvest. Reliable creel census survey data are not available for Mammoth Creek. Angling pressure and success (harvest) can vary among locations along the creek, as well as vary temporally with weather, runoff and demographic patterns, which could affect population estimation of larger (than YOY) trout. In fact, Salamunovich (2006) reported indirect evidence (discarded fishing tackle, parked vehicles) of relatively heavy angling pressure at certain sample sites, as well as direct evidence (persons actively angling near the sample sites) during the 2006 fish survey in Mammoth Creek.

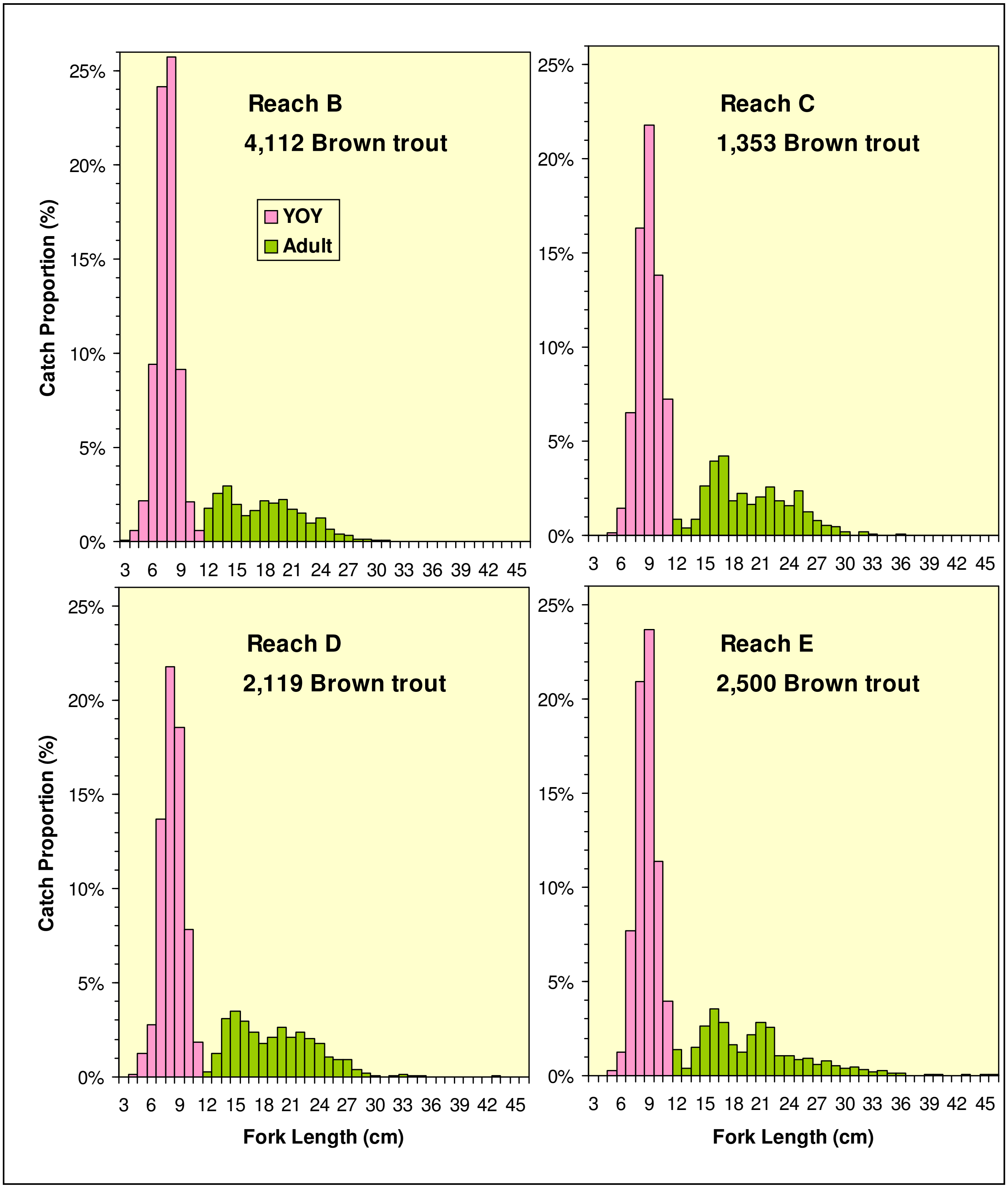

Figure 3. Length distributions of brown trout captured at Reaches B, C, D and E over the 16 annual Mammoth Creek fish community surveys. Tick marks are the lower boundaries of 1-cm size intervals. For example, the length class labeled 12 cm contains fish with fork lengths greater or equal than 120 mm but less than 130 mm.

Table 2. Estimated YOY brown trout abundance (i.e., $\hat{Y}_i$) and variance ((i.e., $V\hat{a}r(\hat{Y}_i)$) for each sample site for the annual 1988-2007 Mammoth Creek fish community surveys. Fish with fork lengths less than 120 mm were considered YOY.

YEAR	Estimate	BH	BL	CH	CL	DH	DL	EH	EL
1988	$\hat{Y}_i$	47	64	18	30	22	13	62	1
	$V\hat{a}r(\hat{Y}_i)$	860.25	38.16	0.95	2.93	0.50	0.25	2.92	0.00
1992	$\hat{Y}_i$	99	37	28	26	56	73	198	3
	$V\hat{a}r(\hat{Y}_i)$	6.48	2.33	2.79	1.20	4.88	0.44	3.51	0.56
1993	$\hat{Y}_i$	80	52	20	70	37	12	54	0
	$V\hat{a}r(\hat{Y}_i)$	124.21	5.85	3.61	64.59	0.63	0.53	5.99	0.00
1994	$\hat{Y}_i$	161	55	40	14	218	62	133	13
	$V\hat{a}r(\hat{Y}_i)$	54.05	2.91	113.91	0.00	17.90	8.07	846.00	0.11
1995	$\hat{Y}_i$	29	31	16	4	32	1	22	3
	$V\hat{a}r(\hat{Y}_i)$	13.94	6.58	12.70	0.30	12.56	0.00	286.05	0.00
1996	$\hat{Y}_i$	251	3	53	8	92	42	40	21
	$V\hat{a}r(\hat{Y}_i)$	1,158.79	0.50	9.39	1.12	28.05	1,019.65	24.08	0.50
1997	$\hat{Y}_i$	437	35	60	8	25	67	154	73
	$V\hat{a}r(\hat{Y}_i)$	112.93	3.65	3.10	0.26	8.98	2.26	4.34	3.97
1999	$\hat{Y}_i$	245	61	51	11	98	12	82	96
	$V\hat{a}r(\hat{Y}_i)$	551.40	111.75	5.50	1.04	96.81	0.28	5.24	26.69
2000	$\hat{Y}_i$	359	18	45	0	31	46	37	101
	$V\hat{a}r(\hat{Y}_i)$	535.64	11.56	2.65	0.00	2.75	1.22	3.19	31.30
2001	$\hat{Y}_i$	229	84	72	12	55	48	67	20
	$V\hat{a}r(\hat{Y}_i)$	237.59	11.04	4.13	0.28	2.58	20.96	29.54	0.35
2002	$\hat{Y}_i$	309	40	20	6	18	51	67	11
	$V\hat{a}r(\hat{Y}_i)$	324.50	6.45	1.10	0.22	11.56	10.16	8.68	1.61
2003	$\hat{Y}_i$	145	17	88	39	20	37	39	30
	$V\hat{a}r(\hat{Y}_i)$	99.76	1.38	183.14	2.47	0.54	11.36	3.33	0.05
2004	$\hat{Y}_i$	159	10	48	15	27	48	44	14
	$V\hat{a}r(\hat{Y}_i)$	170.09	0.74	61.81	0.08	3.60	2.58	5.84	1.51
2005	$\hat{Y}_i$	63	42	22	5	7	23	10	1
	$V\hat{a}r(\hat{Y}_i)$	127.08	1.20	0.92	0.00	0.18	3.37	0.18	3.00
2006	$\hat{Y}_i$	172	3	17	10	29	1	54	60
	$V\hat{a}r(\hat{Y}_i)$	163.35	0.56	3.99	7.31	53.22	0.00	9.04	8.61
2007	$\hat{Y}_i$	261	7	76	41	153	90	207	135
	$V\hat{a}r(\hat{Y}_i)$	321.74	12.96	7.28	168.74	11.30	106.65	49.32	2.50

Table 3. Amounts of catchable-sized rainbow trout planted in Mammoth Creek during recent years. Data provided by CDFG (from Salamunovich 2006).

Year	Number	Pounds	Average Weight/Fish (pounds)
2004	12,426	7,367	0.89
2005	13,109	7,200	0.55
2006	14,583	7,250	0.54
Average	13,373	7,272	0.66

However, during certain years of the 16-year study period, relatively few or no YOY wild rainbow trout were captured: at any sample sites in 1988; at sites BH, BL, EH and EL in 1992; at all sites but DH in 1993; at sites BL, CH, DH, EH and EL in 1995; at sties BL, CH and EL in 2001; and at sites CH, CL and EL in 2003. In addition, abundance estimation based upon those years with low sample site YOY catches result in unreliable and often unbounded population estimates, because the specific catch pattern of the multiple-pass depletion estimator (e.g., 1-0-0, 5-0-0; 1-0-2; etc.) did not allow estimation of standard errors for individual sample-site population estimates. Population estimates of YOY wild rainbow trout among years, reaches and sample sites render problematic the quantitative evaluation (e.g., through least squares regression analysis) of temporal trends and potential relationships between YOY wild rainbow trout abundance and flow.

For the above reasons, annual rainbow trout ("wild" or hatchery) population estimates are of limited value in the assessment of inter-annual trends or potential relationships between abundance and flow in Mammoth Creek.

4.3.1 Brown Trout Data Utilization

For the analysis of brown trout abundance at Mammoth Creek the following fish community survey information was utilized:

- The estimated brown trout abundance (i.e., $\hat{Y}_i$) and variance ((i.e., $\hat{Var}(\hat{Y}_i)$) per sampled reach site (e.g., BH, BL, CH, CL, etc), obtained through a multiple-pass depletion algorithm (Zippin 1956, 1958; White *et al.* 1982) executed by *Microfish 3.0* software (Van Deventer and Platts 1986) and reported annually as an appendix in the Mammoth Creek Fish Community Survey final reports (**Table 4**).

The data from Table 4 were used to evaluate the annual brown trout abundances and variances over the entire creek.

4.4 ANALYTICAL PROCEDURE

4.4.1 Brown Trout Abundance

The annual abundance of brown trout over the entire sample area (i.e., reaches B + C + D + E) was estimated using Hankin's formula for a two-stage design with equal-sized primary units (Hankin 1984; 1986):

$$\hat{Y}_{\mathrm{T}} = \frac{N}{n} \times \sum_{i=1}^{n} \hat{Y}_i \,, \qquad \textbf{(1)}$$

where $\hat{Y}_{\mathrm{T}}$ is the estimated abundance of brown trout over the entire study area in a particular surveyed year, and $\hat{Y}_i$ is the brown trout abundance in sampled site i for the corresponding survey year, obtained through the multiple-pass Zippin's depletion algorithm. N is the total number of potential sampling sites for the particular year (e.g., N = 473 in 1988 and N = 158 from 1992, Table 1), and n is the total number of sampling sites electrofished that particular year (e.g., n = 8 in 1988 and 1992-2007).

Table 4. Estimated brown trout abundance (i.e., $\hat{Y}_i$) and variance ((i.e., $V\hat{a}r(\hat{Y}_i)$) for each sample site for the annual 1988-2007 Mammoth Creek fish community surveys.

YEAR	Estimate	BH	BL	CH	CL	DH	DL	EH	EL
1988	$\hat{Y}_i$	60	89	21	36	38	20	81	2
	$V\hat{a}r(\hat{Y}_i)$	18.09	9.85	0.72	2.45	1.20	0.35	4.25	1.08
1992	$\hat{Y}_i$	173	105	32	48	79	90	226	11
	$V\hat{a}r(\hat{Y}_i)$	5.74	1.81	2.59	2.94	6.77	0.59	4.68	1.26
1993	$\hat{Y}_i$	168	151	29	70	60	29	70	9
	$V\hat{a}r(\hat{Y}_i)$	132.37	10.31	7.56	64.59	0.90	1.25	4.36	0.64
1994	$\hat{Y}_i$	237	128	46	30	251	90	140	23
	$V\hat{a}r(\hat{Y}_i)$	54.42	2.57	23.06	1.18	18.54	10.20	177.74	0.04
1995	$\hat{Y}_i$	100	31	19	6	35	1	19	59
	$V\hat{a}r(\hat{Y}_i)$	17.00	3.84	10.23	0.10	11.53	0.00	11.13	0.44
1996	$\hat{Y}_i$	276	9	74	9	108	36	51	65
	$V\hat{a}r(\hat{Y}_i)$	686.65	0.07	7.13	0.90	21.05	19.39	20.12	0.23
1997	$\hat{Y}_i$	488	40	96	12	35	94	217	102
	$V\hat{a}r(\hat{Y}_i)$	125.64	5.69	7.31	0.28	18.84	4.05	6.90	5.77
1999	$\hat{Y}_i$	303	76	97	17	125	35	124	125
	$V\hat{a}r(\hat{Y}_i)$	246.05	48.55	18.10	0.66	27.45	3.04	4.39	18.27
2000	$\hat{Y}_i$	379	36	62	5	46	66	67	128
	$V\hat{a}r(\hat{Y}_i)$	370.95	2.45	5.81	0.03	1.22	1.84	11.22	27.01
2001	$\hat{Y}_i$	268	97	85	14	65	66	83	30
	$V\hat{a}r(\hat{Y}_i)$	151.59	9.31	4.54	0.40	2.67	11.57	19.72	0.26
2002	$\hat{Y}_i$	331	51	60	14	32	95	106	15
	$V\hat{a}r(\hat{Y}_i)$	234.24	9.33	2.20	0.37	7.04	4.92	7.20	0.91
2003	$\hat{Y}_i$	163	26	108	53	35	81	79	35
	$V\hat{a}r(\hat{Y}_i)$	97.04	0.07	58.16	2.44	3.04	4.25	1.86	0.04
2004	$\hat{Y}_i$	181	25	74	48	50	88	77	33
	$V\hat{a}r(\hat{Y}_i)$	62.92	0.14	1.88	5.02	2.72	2.28	4.74	3.40
2005	$\hat{Y}_i$	75	45	36	11	22	49	38	32
	$V\hat{a}r(\hat{Y}_i)$	84.86	1.06	2.88	0.11	0.46	5.95	0.65	1.05
2006	$\hat{Y}_i$	186	17	27	17	70	16	69	81
	$V\hat{a}r(\hat{Y}_i)$	109.39	0.15	2.99	3.99	10.98	0.31	5.31	6.90
2007	$\hat{Y}_i$	284	14	98	44	194	99	233	173
	$V\hat{a}r(\hat{Y}_i)$	169.68	5.74	4.33	54.51	9.27	32.68	41.10	2.20

The estimated variance for the annual abundance estimates (Hankin 1984, 1986) was calculated as:

$$\hat{V}\left(\hat{Y}_{\mathrm{T}}\right)=\frac{N\times\left(N-n\right)\times\sum_{i=1}^{n}\left(\hat{Y}_i-\bar{Y}\right)^2}{n\times\left(n-1\right)}+\frac{N}{n}\times\sum_{i=1}^{n}V\hat{a}r(\hat{Y}_i),\quad \textbf{(2)}$$

where $\bar{Y}=\sum_{i=1}^{n}\hat{Y}_i \Big/ n$, and $V\hat{a}r(\hat{Y}_i)$ are the site-specific variances from Table 2.

For illustrative purposes only, approximate 95% confidence intervals were calculated for the annual abundance of brown trout using the formula suggested in Skalski and Robson (1992) to correct for normality and provide more realistic confidence intervals. This formula expresses the 95% confidence interval as:

$$P\left(\hat{Y}_{\mathrm{T}} \times e^{-Z_{1-0.05/2} \times \sqrt{\hat{V}(\hat{Y}_{\mathrm{T}}) / \hat{Y}_T^2}} \le Y_{\mathrm{T}} \le \hat{Y}_{\mathrm{T}} \times e^{-Z_{0.05/2} \times \sqrt{\hat{V}(\hat{Y}_{\mathrm{T}}) / \hat{Y}_T^2}} \right) = 1 - 0.05\,, \quad \textbf{(3)}$$

where $Z_{1-0.05/2}$ and $Z_{0.05/2}$ are the inverse of the standard normal cumulative distribution with probabilities 0.975 and 0.025, respectively.

YOY Brown Trout Abundance

The annual abundance of YOY brown trout over the entire sample area and its corresponding variance and approximate 95% confidence intervals were calculated by applying equations (1), (2) and (3) to the *Microfish* estimates of abundance and variance per sampled site and year.

4.4.2 YOY Brown Trout Density

Because the formula for the estimation of annual abundances (equation 1) is based on an expansion of the sum of sample-sites abundances, obtained from the multiple-pass Zippin's depletion algorithm, to the number of potential sampling sites, and this in turn depends on the reach lengths, annual average YOY brown trout densities also were calculated.

First, $D_{R,j}$, the YOY brown trout densities at each of the sampled sites were calculated by dividing the estimated abundances from Table 2 by the length of the sample site displayed in Table 1.

Second, for subsequent trend analyses, three annual averages of YOY brown trout densities were calculated.

1) *Average density for the entire creek ($\bar{D}_{\mathrm{T}}$)*

$\bar{D}_{\mathrm{T}}$ was calculated as $\bar{D}_{\mathrm{T}} = \sum_{R=1}^{4} \sum_{j=1}^{2} D_{R,j} / n$, where $D_{R,j}$ is the YOY brown trout density in reach R and sampling site *j*, and n is the total number of sample sites electrofished during the year (e.g., n = 8 in 1988 and 1992-2007).

2) *Average density at a particular reach ($\bar{D}_R$)*

$\bar{D}_R$ was calculated as $\bar{D}_R = \sum_{j=1}^{2} D_{R,j} / n_R$, where n_R is the number of sample sites electrofished at reach R during the year (two sites sampled within each reach, annually).

3) Average three-reach density ($\bar{D}_R^{'}$)

$\bar{D}_R^{'}$ was calculated as $\hat{D}_{\mathrm{T}}^{'} = \sum_{R \neq W}^{3} \sum_{j=1}^{2} D_{R,j} \Big/ (n - n_W)$, where W indicates the reach excluded from the calculation. The three-reach annual average densities were used to appraise the relative importance of a particular reach in the average annual density for the entire creek (see Temporal Trend Analyses, below).

Temporal Trend Analyses

Minimum least squares was utilized to estimate the slope (β) and intercept (α) of simple linear models (i.e., $Y = \alpha + \beta \times X$) relating the response variable Y (e.g., annual abundance or average densities) to a temporal variable X whose values were obtained by subtracting 1987 from the survey year (e.g., the X value for year 1992 was x = 1992 - 1987 = 5). From these linear models a decline in Mammoth Creek brown trout population can be inferred whenever the fit of the models to the abundance or density data provide statistically significant negative slopes (i.e., $\hat{\beta} < 0$).

Temporal trend analyses were conducted for the overall (all age classes) annual brown trout population estimates (number of fish), as well as separately for annual YOY brown trout population estimates for the entire creek (i.e., Sherwin St. crossing to the confluence with Hot Creek). In addition, temporal trend analysis was conducted for average annual YOY brown trout density (fish/mile) estimates for the entire creek, and on a reach-by-reach basis for the 16-year period of record.

Additional temporal trend analyses of annual YOY brown trout densities emphasized recent years (1999 through 2007) because: (1) the recent period represents an uninterrupted sequence of annual fish population sampling; (2) the period 1999-2007 is characterized by a generally "wetter" hydrology than the period extending from 1988-1997; and (3) MCWD has been operating in accordance with the proposed bypass flow requirements identified in the Beak (1991) report since August 1996, when the Mono County Superior Court issued a ruling requiring implementation of the proposed bypass flow requirements. Thus, temporal trend analyses were conducted for average annual YOY brown trout densities (fish/mile) for the entire creek, and on a reach-by-reach basis for recent years (1999-2007).

Also for recent years (1999-2007), temporal trend analyses were conducted to examine the potential influence of specific reaches (i.e., B, C, D or E) to overall temporal trends by removing the average annual YOY brown trout density for a specific reach, recalculating average annual densities for the entire creek for the remaining three reaches, and repeating the regression analysis to obtain temporal trends. Then, regression statistics (i.e., r^2 and P values) and resultant slopes of the fitted regressions were compared between the "with" and "without" specific reach scenarios. This process was conducted for each of the specific reaches (i.e., B, C, D or E).

4.4.3 Potential Relationships Between YOY Brown Trout Density and Flow

Mammoth Creek daily mean flows measured at the Old Mammoth Road (OMR) gage during the years 1987 through 2007 were utilized to calculate two flow metrics that were used, in turn, as explanatory, or independent, variables in simple linear regression analyses performed on the annual averages of YOY brown trout densities for the entire creek (i.e., $\bar{D}_T$) to examine potential relationships between YOY brown trout densities and flows.

The first flow variable, hereinafter referred to as OMR Low Flow Quartile, was used to represent the low summer flows, and was defined as the average of all daily flows lower than the 25th percentile of the cumulative distribution of all daily flows at the Old Mammoth Road gage from the day of the annual spring/summer maximum daily flow through the day before the start of the annual electrofishing survey.

The second flow variable, hereinafter referred to as OMR High Flow, was calculated as the highest 7-day running average of the mean daily flows during a particular year, which serves as an index of the annual spring/early summer peak runoff.

For both OMR Low Flow Quartile and OMR High Flow, linear regression analyses were conducted using the flow variables as independent (explanatory) variables and average annual YOY brown trout densities for the entire creek as the dependent variable for the 16-year period of record.

Table 5 displays the values of OMR Low Flow Quartile and OMR High Flow, as well as the dates involved in the calculations. As an example, **Figure 4** illustrates the OMR daily flows during 2003 and their relationship to the values of OMR Low Flow Quartile and OMR High Flow during that year.

Potential relationships between YOY brown trout densities and flows during the low flow period were further examined using an alternate expression of low flows, hereinafter referred to as OMR Low Flow. First, the average flow at OMR was calculated for each of the low flow months (August, September, and October) over the 16 years included in the analysis. Second, the month with the lowest average flow (among August, September, and October) for each of the 16 years was identified. Third, linear regression analysis was conducted using the flow variable as the independent (explanatory) variable, and average annual YOY brown trout densities for the entire creek as the dependent variable for the 16 years included in the analysis.

It was suggested by the Mammoth Creek Technical Team, comprised of various stakeholders including CDFG, USGS, LADWP, non-governmental organizations (NGOs) and others, in August 2006 that streambed cleansing (via scouring flows) may result in additional substrate interstitial space availability for the colonization of benthic macroinvertebrates. It was further suggested that these potentially "improved" habitat conditions (i.e., increased macroinvertebrate production as a food supply) for YOY trout rearing may not be evident in YOY trout densities within a year due to the potential flushing (or displacement) of YOY trout from their habitats, but may be reflected by YOY trout densities in the subsequent year. To examine this potential phenomenon, OMR High Flow variables were lagged backward by one year, then regressed against the annual average YOY brown trout densities for the entire creek for the 16-year period of record. For example, OMR High Flow during 1992 was regressed against average YOY brown trout density during 1993, OMR High Flow during 1993 regressed against average YOY brown trout density during 1994, and so forth.

Table 5. Flow variables used in regressions with annual averages of YOY brown trout densities. Flows were measured at the Old Mammoth Road (OMR) gage. OMR high flow was calculated as the highest 7-day running average of the daily mean flows of each particular year. OMR low flow quartile was defined as the average of all daily flows lower than the 25th percentile of all daily flows, from the day of the annual spring/summer maximum through the day before the start of the annual electrofishing survey. Light yellow cells mark years with annual electrofishing surveys.

YEAR	OMR Low Flow Quartile			OMR High Flow	
	Daily Maximum Date	Eve of Survey Start Date	Flow (cfs)	7-Day-MA Maximum Date	Flow (cfs)
1987	05/15	*N/A*	*N/A*	05/12	59.6
1988	05/23	11/01	4.5	05/23	50.2
1989	05/10	*N/A*	*N/A*	05/09	46.2
1990	06/11	*N/A*	*N/A*	06/07	34.1
1991	06/14	*N/A*	*N/A*	06/09	84.6
1992	05/12	10/20	5.0	05/12	40.6
1993	06/29	10/11	8.1	06/15	120.2
1994	06/01	10/03	5.9	05/31	61.8
1995	07/11	10/31	11.8	07/06	214.8
1996	05/17	10/02	10.0	05/15	158.7
1997	06/02	10/03	10.0	05/30	109.2
1998	07/11	*N/A*	*N/A*	07/01	172.3
1999	06/17	09/23	8.9	06/16	112.4
2000	05/29	10/09	6.6	05/24	109.9
2001	05/18	10/08	5.8	05/22	85.2
2002	06/02	09/29	6.1	05/31	78.0
2003	05/30	09/28	6.3	05/29	129.7
2004	05/29	10/03	6.1	05/29	56.6
2005	06/15	09/28	8.5	06/11	148.1
2006	06/07	10/10	8.7	06/05	196.2
2007	05/19	10/09	5.0	05/17	36.7

5.0 RESULTS

5.1 NATIVE FISH ABUNDANCE

Native fishes, including Owens sucker and tui chub, are generally found in only the lower reaches of Mammoth Creek, particularly in the lowermost reach (Reach E). The numbers of Owens sucker and tui chub captured during the electrofishing surveys in Reach E during each year of the 16-year period of record are shown in **Table 6**. Clearly, native fishes were more abundant through the mid-1990s than during later years. Salamunovich (2006) suggested that these native fishes in lower Mammoth Creek may be near the limits of their physical range and are able to expand their populations during extended periods of “drier” hydrology, such as that which occurred during the early 1990s.

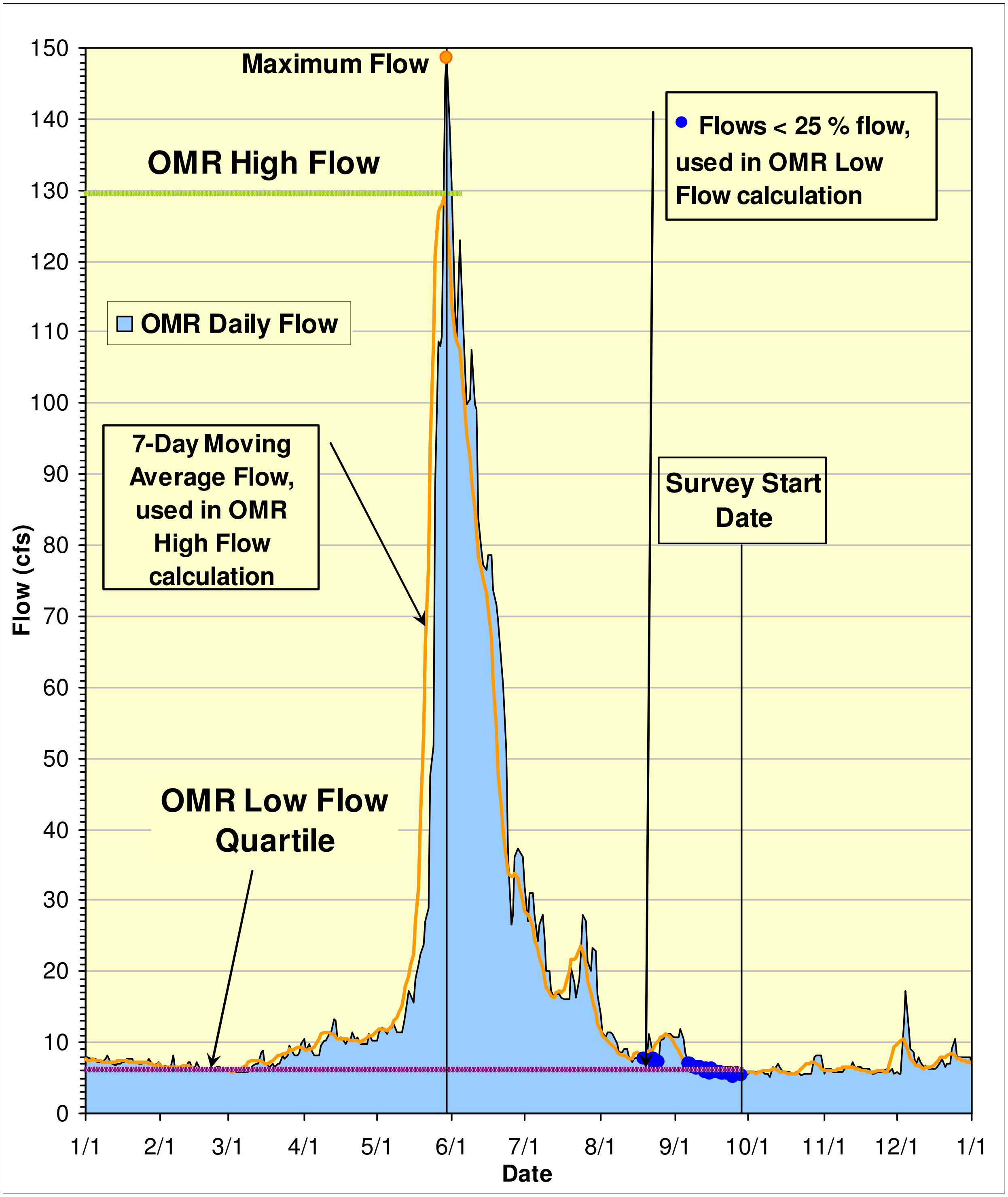

Figure 4. Daily OMR flows in 2003 and their relationship to the values of OMR low flow quartile and OMR high flow used in the study of potential relationships between YOY brown trout densities and flows.

Table 6. Numbers of Owens sucker and tui chub captured during electrofishing surveys in the lowermost reach (Reach E) of Mammoth Creek, 1988-2007.

Year	Owens sucker	Tui chub
2007	42	1
2006	11	6
2005	18	2
2004	122	30
2003	54	19
2002	2	2
2001	6	2
2000	18	2
1999	49	6
1997	2	2
1996	84	48
1995	58	69
1994	524	392
1993	425	855
1992	205	417
1988	37	19

5.2 STANDARDIZED TROUT ABUNDANCE

5.2.1 Rainbow Trout

For the 16-year period of record, the overall annual abundance of "wild" rainbow trout averages 377 fish per mile (**Table 7**). By far, the highest annual average was during 2000, when about 4.4 times the annual average number of "wild" rainbow trout per mile (1,377) were present, relative to overall annual average (310 trout per mile) for the remaining 15 years of monitoring. Overall average annual abundance (number/mile) of "wild" rainbow trout was generally highest in the reaches (C and D) located in the "middle" of Mammoth Creek.

Visual examination of potential temporal trends in the average annual abundance (number/mile) of "wild" rainbow trout was facilitated by locally weighted regression smoothing obtained with S-plus© function loess (**Figure 5**). Examination of Figure 5 suggests that "wild" rainbow trout abundance (fish/mile) is somewhat cyclic over the 16-year period of record. The locally weighted regression smoothing suggests a period of increasing abundance from 1988 to 2000. From 2001, "wild" rainbow trout abundance declined to 2004. During the last 3 years, "wild" rainbow trout appear to have initiated a new period of increasing abundance. As previously mentioned, however, "wild" rainbow trout data must be interpreted with caution because of the confounding influences associated with the identification of "wild" versus hatchery rainbow trout, and the unaccounted for variation in hatchery planting practices and recreational angling harvest.

Table 7. Standardized abundance estimates[1] (number/mile) for "wild" rainbow trout captured at each of the Mammoth Creek electrofishing sites, 1988-2007. Bold numbers indicate the highest value for each site.

	Sample Site								
	BH	BL	CH	CL	DH	DL	EH	EL	Annual Mean
2007	680	55	123	85	429	431	225	174	275
2006	819	110	282	239	413	359	902	366	436
2005	493	282	70	0	158	158	141	475	222
2004	422	246	123	35	229	246	88	18	176
2003	669	194	106	35	211	282	158	0	207
2002	**1,039**	**810**	123	123	528	475	229	18	418
2001	616	106	88	722	563	422	493	18	379
2000	35	616	405	**6,354**	528	669	**2,253**	158	**1,377**
1999	123	669	546	1,179	686	510	334	194	530
1997	123	123	810	933	722	**1,021**	810	88	579
1996	282	18	**1,690**	528	**933**	229	458	**563**	588
1995	158	0	53	59	18	88	53	194	78
1994	35	0	581	1,654	387	616	106	0	422
1993	18	0	70	0	299	35	53	18	62
1992	70	0	141	651	546	229	141	0	222
1988	53	0	106	0	106	158	53	0	59
1988-2007	352	202	332	787	422	371	406	143	377

[1] Modified (by the incorporation of 1988 and 2007 data) from Salamunovich (2006).

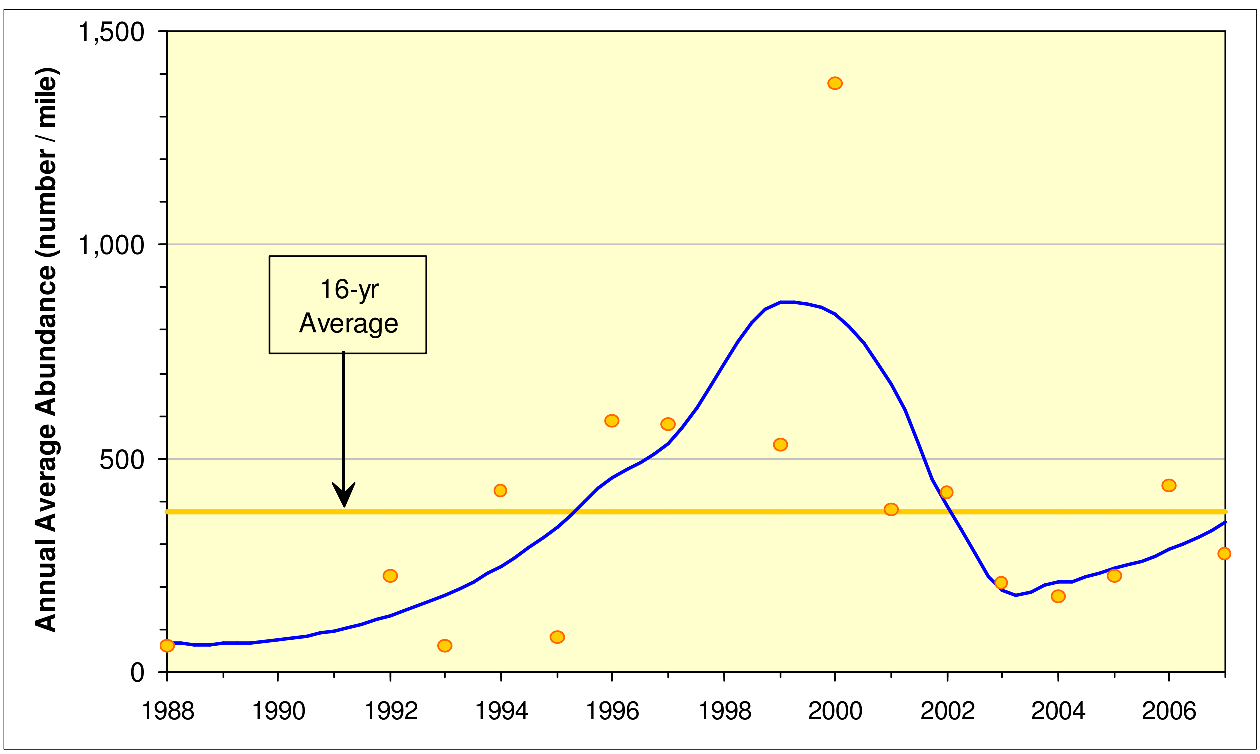

Figure 5. Standardized average annual abundance estimates (number/mile) for "wild" rainbow trout during each year of monitoring, compared to the overall annual average abundance over the 16-year period of record. The blue line is the locally weighted regression smoothing of the standardized average annual abundance estimates obtained with S-plus© function loess (Span = 0.55).

5.2.2 Brown Trout

Relative to "wild" rainbow trout, brown trout are much more abundant in Mammoth Creek. For the 16-year period of record, the overall annual abundance of brown trout averages 1,580 fish per mile (**Table 8**). Overall average annual abundance (number/mile) of brown trout is generally highest in the uppermost reach (Reach B) of Mammoth Creek.

Visual examination of potential temporal trends in the average annual abundance (number/mile) of brown trout (**Figure 6**) also suggests a somewhat cyclic fluctuation about the long-term (16-year) average, as was suggested for "wild" rainbow trout. The average annual abundance of brown trout exhibits a decrease from 1988 through 1995, followed by a short period of increased abundance to 1997. From 1998 through 2005 brown trout abundance consistently declined. During the last 2 years, brown trout appear to have initiated a new period of increasing abundance.

5.3 TROUT LENGTH-FREQUENCY

Although site-specific variation in the abundance of size (and presumably age) classes is evident among years, multiple size classes of "wild" rainbow trout are present annually in Mammoth Creek over the 16-year period of record.[2] In general, most of the "wild" trout are represented by YOY size class fish.

Examination of brown trout length-frequencies demonstrates that multiple size/age classes are generally present at all of the 8 sample sites during the 16 annual fish surveys in Mammoth Creek. From the data included in Figure 3, it is evident that the YOY size class dominates the brown trout populations in each reach of Mammoth Creek. Overall, the YOY size comprised approximately 71% of all brown trout captured over the 16 years of sampling in Mammoth Creek. One potential contributor to the high percentage of YOY brown trout in the total population is the unaccounted for influence of recreational angling harvest on the larger (and older) size classes.

5.4 BROWN TROUT ABUNDANCE TEMPORAL TRENDS

Annual brown trout abundance estimates for Mammoth Creek and their 95% confidence intervals are displayed in **Table 9**. The annual abundance estimates exhibit a slight decreasing trend over time which is extremely weak (r^2 =0.05) and non-significant (P =0.40) (**Figure 7**).

Table 10 displays the estimated annual abundances for all brown trout with fork lengths smaller that 120 mm, considered to be YOY brown trout, and their estimated 95% confidence intervals, in Mammoth Creek from 1988 through 2007. Annual YOY abundance estimates exhibit a decreasing trend which is extremely weak (r^2 =0.01) and non-significant (P =0.68) (**Figure 8**).

---

[2] A discussion of site-specific variation in the abundance of "wild" rainbow trout size classes is presented for the 2006 survey in Salamunovich (2006).

Table 8. Standardized abundance estimates[1] (number/mile) for brown trout captured at each of the Mammoth Creek electrofishing sites, 1988-2007. Bold numbers indicate the highest value for each site.

	Sample Site								
	BH	BL	CH	CL	DH	DL	EH	EL	Annual Mean
2007	4,949	258	1,725	752	3,201	**1,778**	**4,378**	**3,015**	**2,507**
2006	3,241	313	475	290	1,155	287	1,297	1,411	1,059
2005	1,320	792	634	194	387	862	704	563	682
2004	3,186	440	1,302	845	880	1,549	1,355	581	1,267
2003	2,869	458	**1,901**	933	616	1,426	1,390	616	1,276
2002	5,826	898	1,056	246	563	1,672	1,866	264	1,549
2001	4,717	1,707	1,496	246	1,144	1,162	1,461	528	1,558
2000	6,670	634	1,074	88	810	1,162	1,179	2,253	1,734
1999	5,333	1,338	1,443	299	2,200	616	2,182	2,200	1,951
1997	**8,589**	704	1,690	211	616	1,654	3,819	1,795	2,385
1996	4,840	158	1,302	158	1,901	634	898	1,144	1,379
1995	1,760	546	334	88	616	18	334	1,038	592
1994	4,171	2,253	810	528	**4,418**	1,584	2,464	405	2,079
1993	2,957	2,658	510	1,232	1,056	510	1,232	158	1,289
1992	3,042	1,848	563	845	1,390	1,584	3,978	194	1,681
1988	3,168	**4,699**	1,109	**1,901**	2,006	1,056	4,277	106	2,290
1988-2007	4,165	1,231	1,089	553	1,435	1,097	2,051	1,017	1,580

[1] Modified (by the incorporation of 1988 and 2007 data) from Salamunovich (2006).

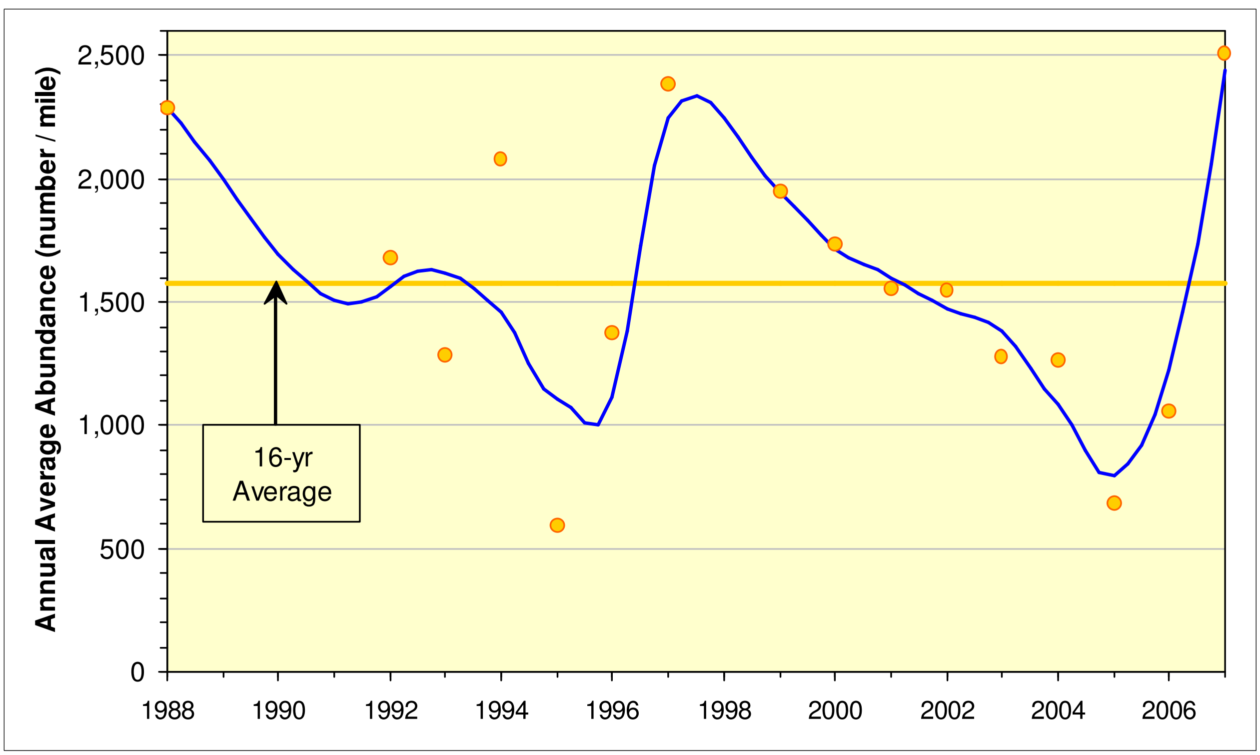

Figure 6. Standardized average annual abundance estimates (number/mile) for brown trout during each year of monitoring, compared to the overall annual average abundance over the 16-year period of record. The blue line is the locally weighted regression smoothing of the standardized average annual abundance estimates obtained with S-plus© function loess (Span = 0.4).

Table 9. Annual brown trout estimated abundance and 95% confidence intervals in Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

YEAR	Abundance $\hat{Y}_T$	95% Confidence Interval
1988	20,516	(12,607 - 33,389)
1989	---	---
1990	---	---
1991	---	---
1992	15,089	(9,033 - 25,204)
1993	11,574	(6,802 - 19,692)
1994	18,664	(11,236 - 31,003)
1995	5,333	(2,793 - 10,181)
1996	12,403	(5,896 - 26,093)
1997	21,409	(9,853 - 46,518)
1998	---	---
1999	17,815	(10,556 - 30,063)
2000	15,583	(6,922 - 35,081)
2001	13,983	(7,723 - 25,316)
2002	13,904	(6,266 - 30,850)
2003	11,455	(7,451 - 17,610)
2004	11,376	(7,170 - 18,049)
2005	6,083	(4,348 - 8,510)
2006	9,539	(5,009 - 18,167)
2007	22,495	(14,402 - 35,136)

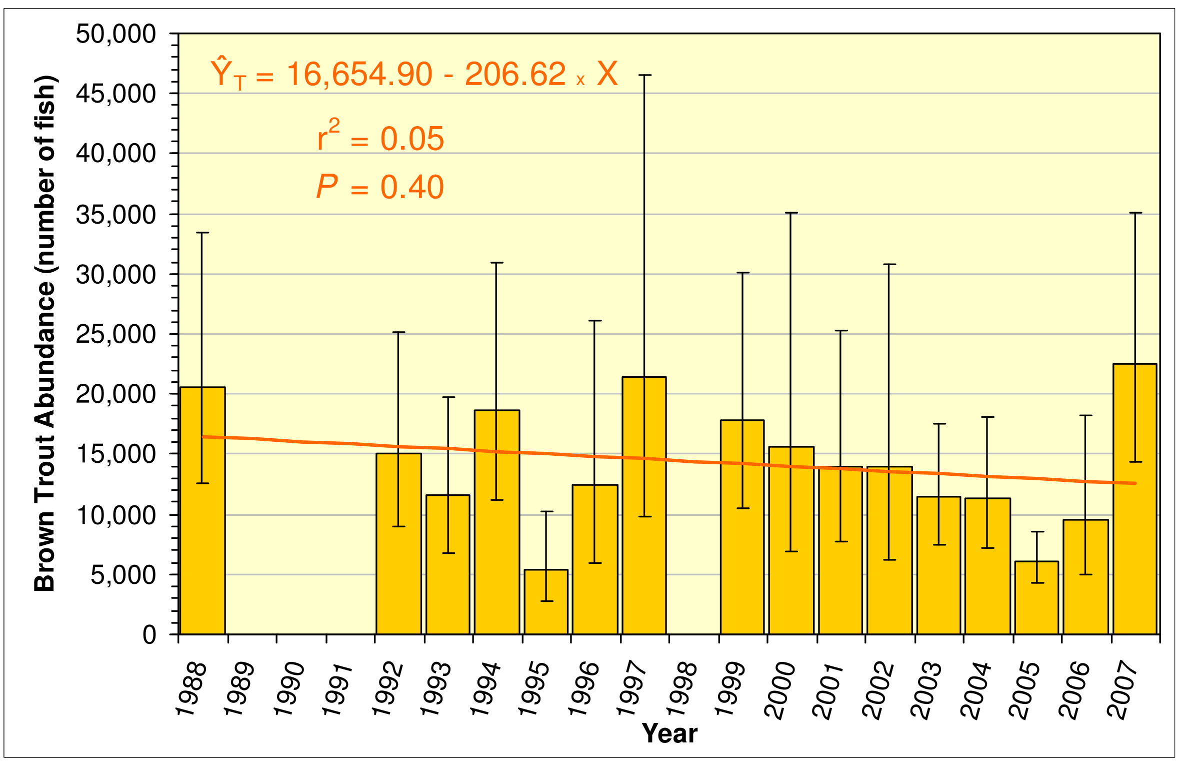

Figure 7. Annual brown trout abundance estimates (bars), estimated 95% confidence intervals (error bars) and fitted regression line for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

Table 10. Annual YOY brown trout abundance and 95% confidence intervals for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

YEAR	Abundance $\hat{Y}_T$	95% Confidence Interval
1988	15,195	(9,241- 24,985)
1989	---	---
1990	---	---
1991	---	---
1992	10,270	(5,419 - 19,462)
1993	6,419	(4,005 - 10,288)
1994	13,746	(7,675 - 24,618)
1995	2,726	(1,623 - 4,576)
1996	10,073	(4,279 - 23,712)
1997	16,965	(7,021 - 40,992)
1998	---	---
1999	12,956	(7,041 - 23,841)
2000	12,581	(4,680 - 33,817)
2001	11,593	(6,224 - 21,595)
2002	10,310	(3,636 - 29,232)
2003	8,196	(4,652 - 14,441)
2004	7,209	(3,519 - 14,766)
2005	3,417	(1,755 - 6,651)
2006	6,834	(2,826 - 16,522)
2007	19,158	(11,931 - 30,762)

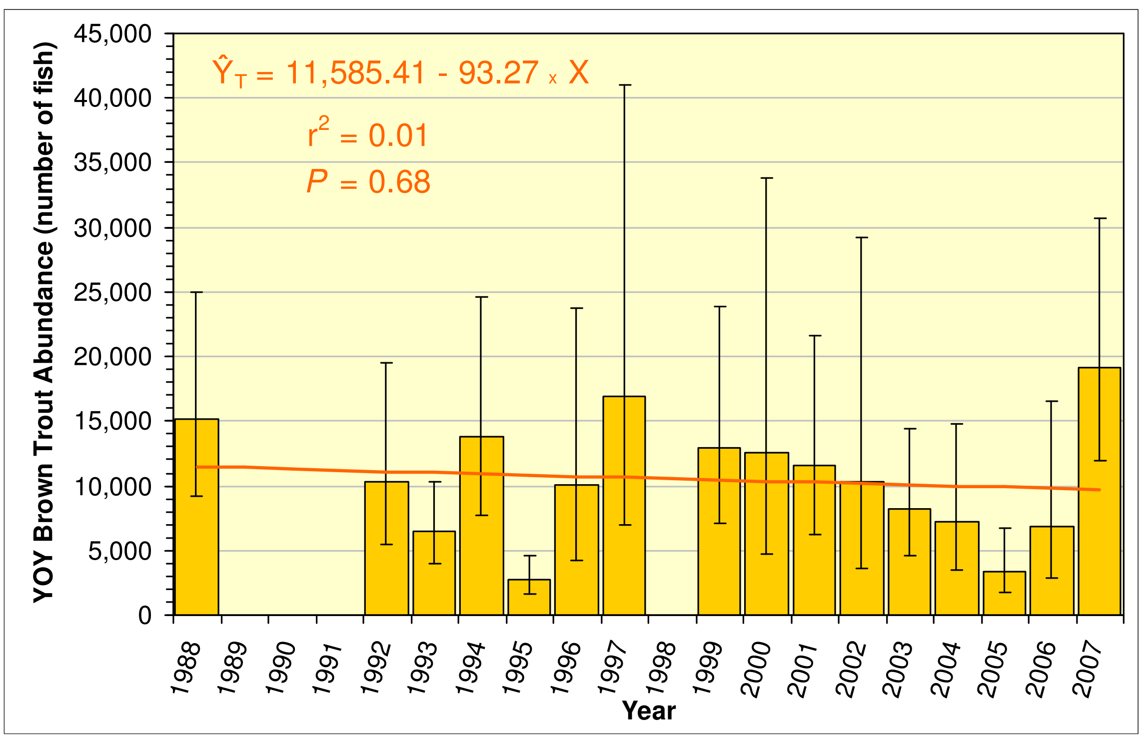

Figure 8. Annual YOY brown trout abundance estimates (bars), estimated 95% confidence intervals (error bars) and fitted regression line for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

5.5 YOY BROWN TROUT DENSITY TEMPORAL TRENDS

Annual YOY brown trout densities, expressed as fish/mile and averaged over the entire Mammoth Creek (i.e., $\bar{D}_T$) exhibit a slight decreasing trend over time, although the trend is extremely weak (r^2 =0.01) and non-significant (P =0.68) (**Figure 9**). The reach- by-reach annual average densities also exhibit extremely weak decreasing trends, none of which are significant (**Figure 10**).

As previously discussed, additional trend analyses of YOY brown trout densities emphasized recent years (1999 through 2007). **Figure 11** displays the non-significant (P =0.76) and extremely weak (r^2 =0.01) decreasing linear temporal trend in the annual average YOY brown trout densities over the period 1999 through 2007. The reach-by-reach trend analysis of annual average YOY brown trout densities over the period 1999-2007 (**Figure 12**) indicates a weak to moderate decreasing liner trend that is moderately significant for Reach B (r^2 =0.42, P = 0.06). By contrast, the remaining three reaches exhibit increasing but extremely weak trends in annual average YOY brown trout densities (r^2 ranging from 0.01 to 0.05), none of which were significant (P ranging from 0.58 to 0.80).

Because the recent annual average YOY brown trout densities displayed in Figure 11 result from averaging the eight sample site densities (two per reach) of each year, and because the reach-by-reach trend analysis of annual average YOY brown trout densities displayed substantial differences among reaches (Figure 12), the relative importance of each particular reach in the average annual densities for the whole reach and their temporal trend was appraised by removing the annual densities of a particular reach, one at a time, recalculating annual average YOY brown trout densities (now based on only three reaches each year), and repeating the regression analysis to obtain corresponding temporal trends. **Figure 13** displays the results of this evaluation.

The estimated decreasing trends (i.e., the regression slopes) are particularly affected when the annual reach densities of Reach B are removed. When the relatively high annual densities of Reach B that display a moderate to weak decreasing trend (see Figure 12) are removed from the annual averaging, the resulting creek annual average YOY brown trout densities (green bars) display a weak increasing temporal trend. This result indicates that, due to the relatively high densities of YOY brown trout in Reach B, combined with the moderate to weak decreasing trend in YOY density in Reach B from 1999 through 2007, the overall slight declining trend in YOY density in Mammoth Creek in recent years is influenced by Reach B. The removal of the annual densities of Reach C, D or E does not appear to substantially affect the temporal trends of the resulting creek annual average YOY brown trout densities in recent years (see blue, pink and violet bars and lines in Figure 13).

5.6 POTENTIAL RELATIONSHIPS BETWEEN YOY BROWN TROUT DENSITY AND FLOW

The annual average YOY brown trout densities for the entire Mammoth Creek during the period 1988 through 2007 were regressed against OMR low flow quartile to assess potential relationships between the annual densities and the low Mammoth Creek flows of late summer and autumn, which precede the surveys each year (Table 5, Figure 4). The linear regression suggests that the annual average YOY brown trout densities are negatively correlated with low Mammoth Creek flows (**Figure 14**). In other words, the observed distribution of the data set and

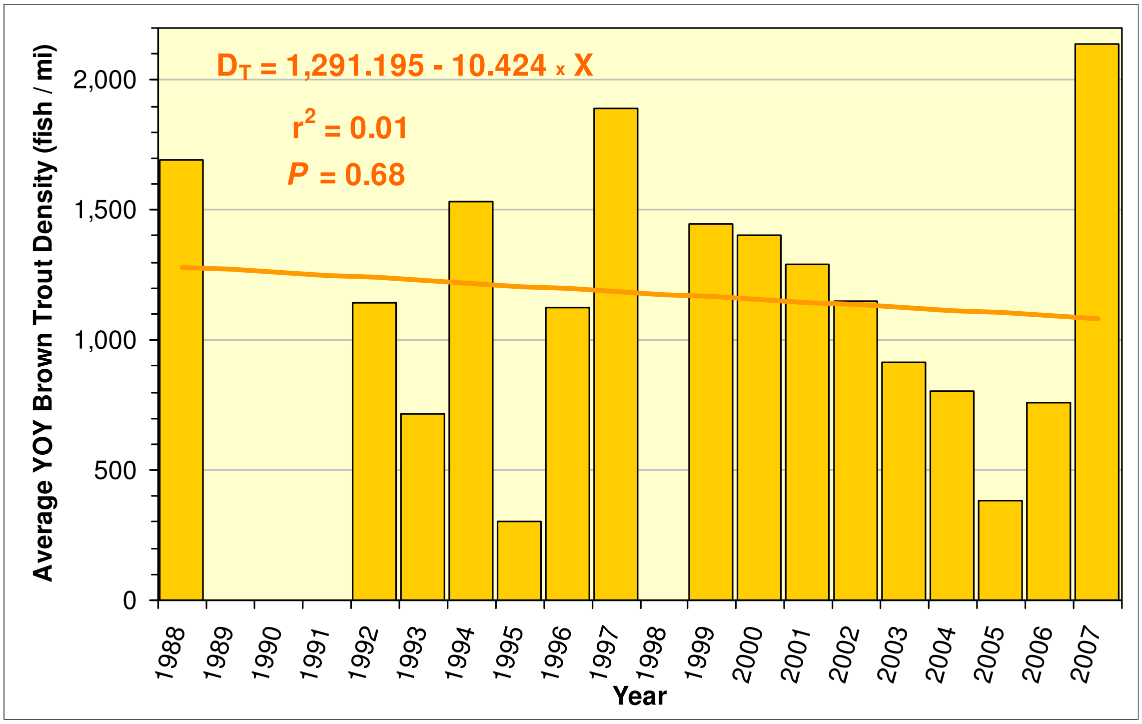

Figure 9. Annual average YOY brown trout density estimates (bars) and fitted regression line for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

resultant slope of the linear regression suggest that YOY brown trout density decreases as the flows during the summer/autumn period increase. However, the relationship is only moderately significant (P =0.08) and weak (r^2 =0.20).

The annual average YOY brown trout densities for the entire Mammoth Creek during the period 1988 through 2007 also were regressed against the lowest average monthly OMR flows (among August, September, and October) for each year to assess potential relationships between the annual densities and the low Mammoth Creek flows of late summer and autumn, which precede the surveys each year. As described for the regression using the average of the low flow quartile as the explanatory variable each year, the linear regression suggests that the annual average YOY brown trout densities are negatively correlated with the lowest average monthly Mammoth Creek flows (at OMR) (**Figure 15**). As previously discussed, the observed distribution of the data set and resultant slope of the linear regression suggests that YOY brown trout density decreases as the flows during the summer/autumn period increase. This relationship is highly significant (P =0.01) and weak to moderate (r^2 = 0.42).

The annual average YOY brown trout densities for the entire Mammoth Creek during the period 1988 through 2007 also were regressed against OMR High Flow to assess potential relationships between the annual densities and the peak Mammoth Creek flows of late spring/early summer (Table 5, Figure 4). The linear regression suggests that the annual average YOY brown trout densities are negatively correlated with the Mammoth Creek late spring/early summer peak flows

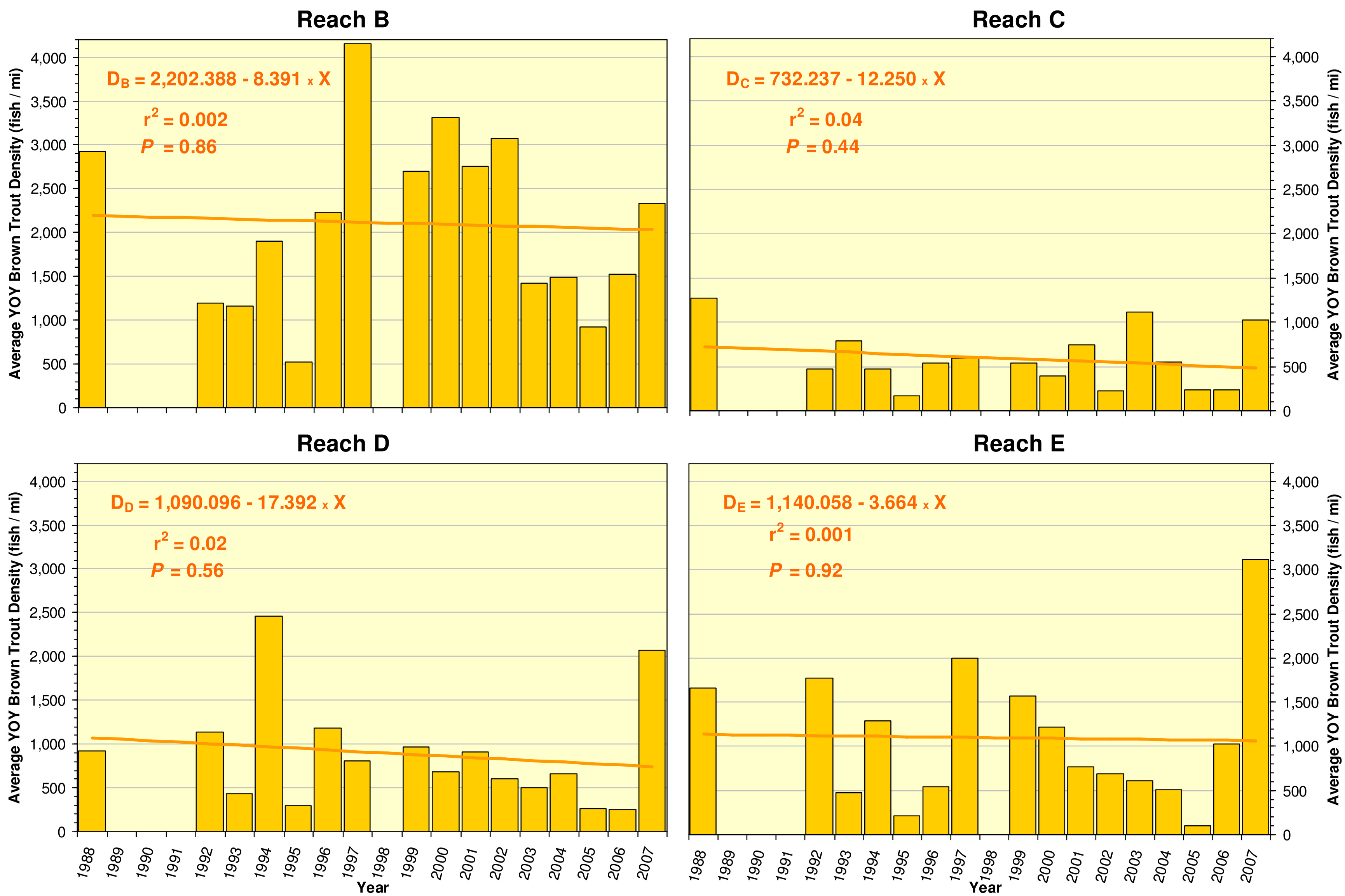

Figure 10. Annual average YOY brown trout density estimates (bars) and fitted regression lines in the four surveyed reaches of Mammoth Creek from 1988 through 2007.

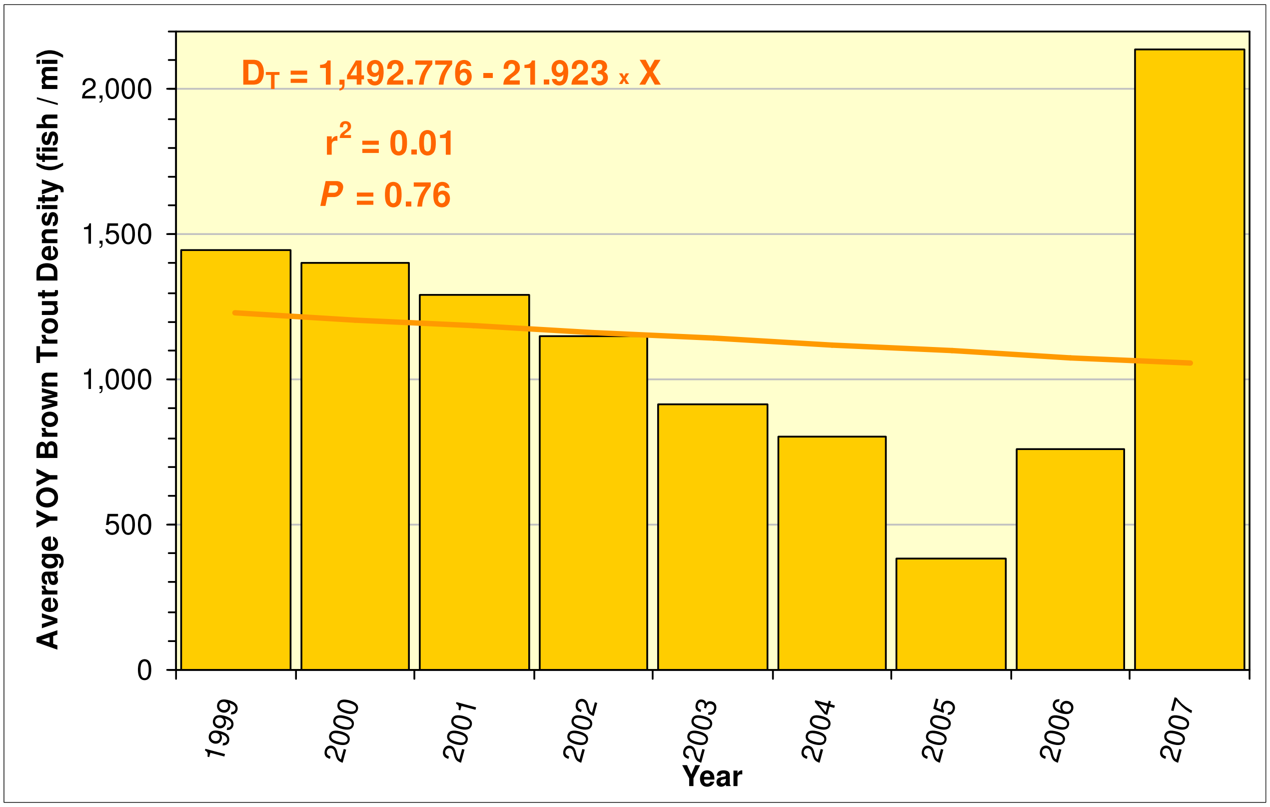

Figure 11. Annual average YOY brown trout density estimates (bars) in Mammoth Creek and the fitted regression line for the period 1999-2007.

(**Figure 16**). The linear relationship was weak to moderate ($r^2 = 0.42$), and highly significant ($P = 0.01$). In other words, the highly significant negative correlation between annual average YOY brown trout density and peak runoff flows during late spring/early summer indicate that high peak flows are associated with low YOY brown trout densities the following autumn. Presumably, high peak runoff flows may scour the streambed and result in the dislodgement of incubating embryos, and/or flushing or displacement of post-emergent YOY brown trout from their habitats.

As previously mentioned, it has been speculated that streambed cleansing (via scouring flows) may result in additional substrate interstitial space availability for the colonization of benthic macroinvertebrates. It was further suggested that these potentially "improved" habitat conditions (i.e., increased macroinvertebrate production as a food supply) for YOY trout rearing may not be evident in YOY trout densities within a year due to potential embryo dislodgement, or flushing (or displacement) of YOY trout from their habitats, but may be reflected by YOY trout densities in the subsequent year. To examine this potential phenomenon, OMR High Flow variables were lagged backward by one year, then regressed against the annual average YOY brown trout densities for the entire creek for the 16-year period of record. The observed distribution of the data set and resultant slope of the linear regression suggest that YOY brown trout density increases with an increase in peak runoff flow that occurred 1 year previously (**Figure 17**). Although the relationship is significant ($P = 0.04$), it is weak ($r^2 = 0.27$).

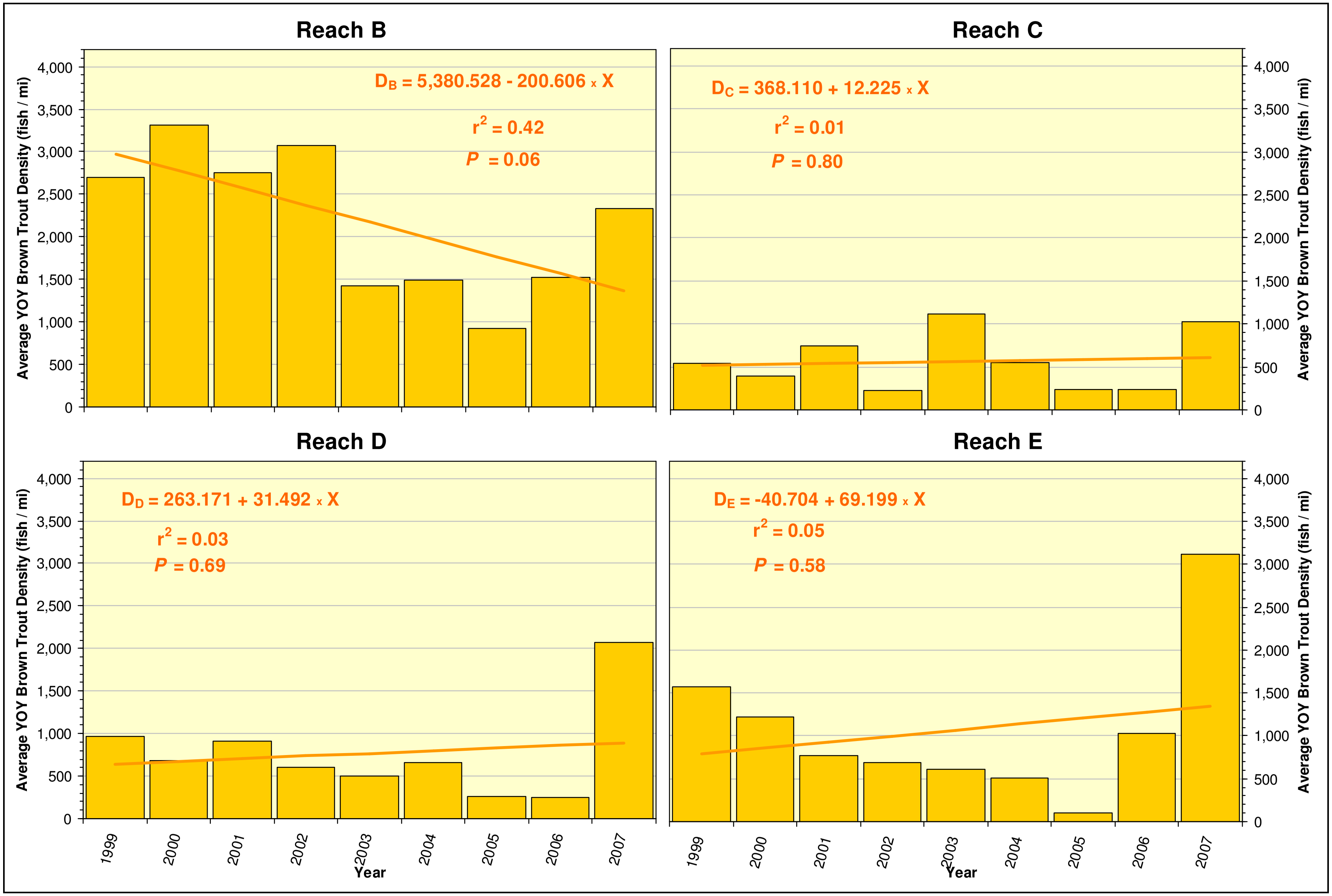

Figure 12. Annual average YOY brown trout density estimates (bars) and fitted regression lines in the four surveyed reaches of Mammoth Creek for the period 1999-2007.

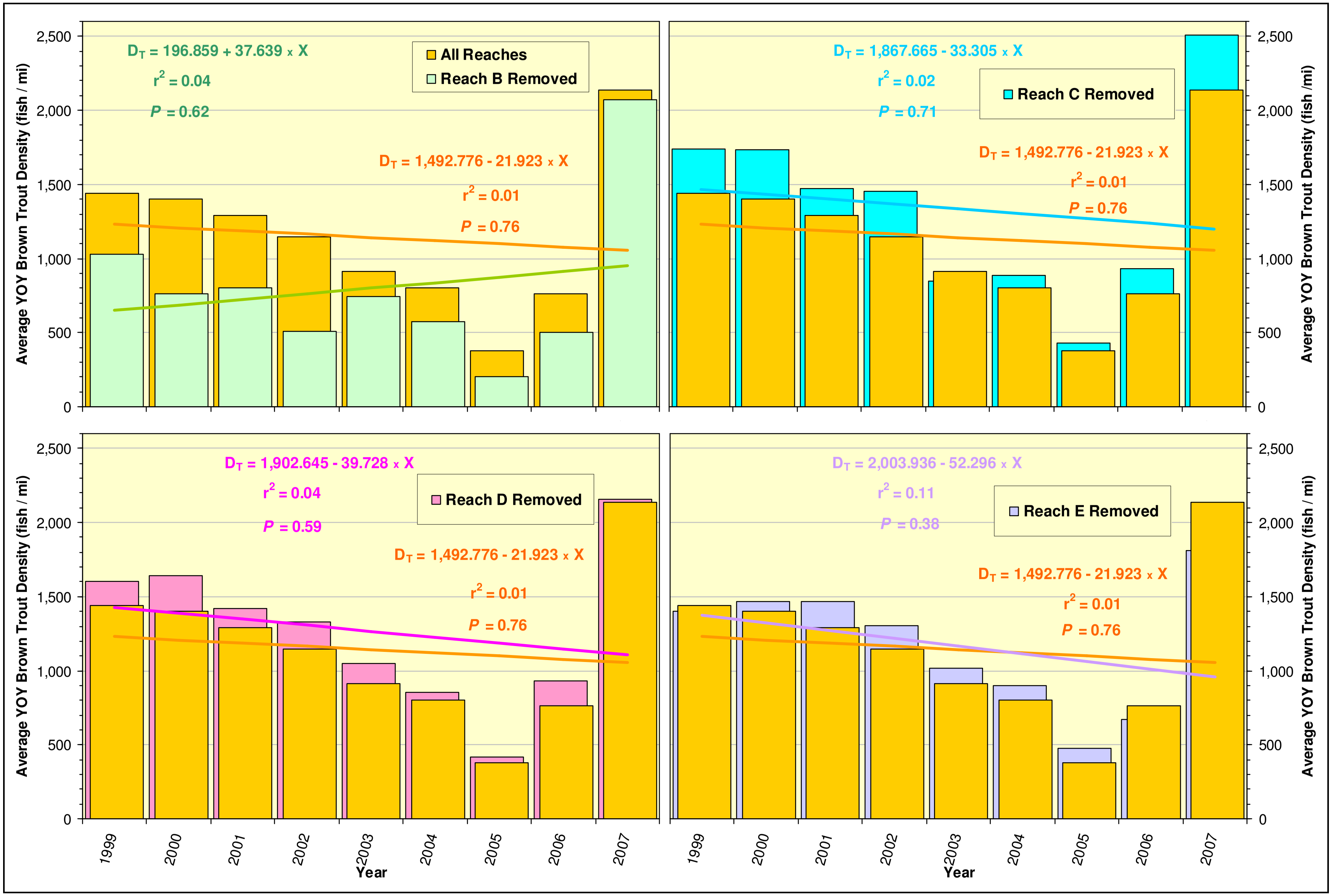

Figure 13. Influence of annual average reach densities on annual average YOY brown trout density trends in Mammoth Creek during 1999-2007. Orange bars and regression lines indicate the trend of creek annual average YOY brown trout density with all sampled reaches; bars and lines in green, blue, pink and violet indicate the trends of the creek average density after removing densities from Reaches B, C, D and E, respectively.

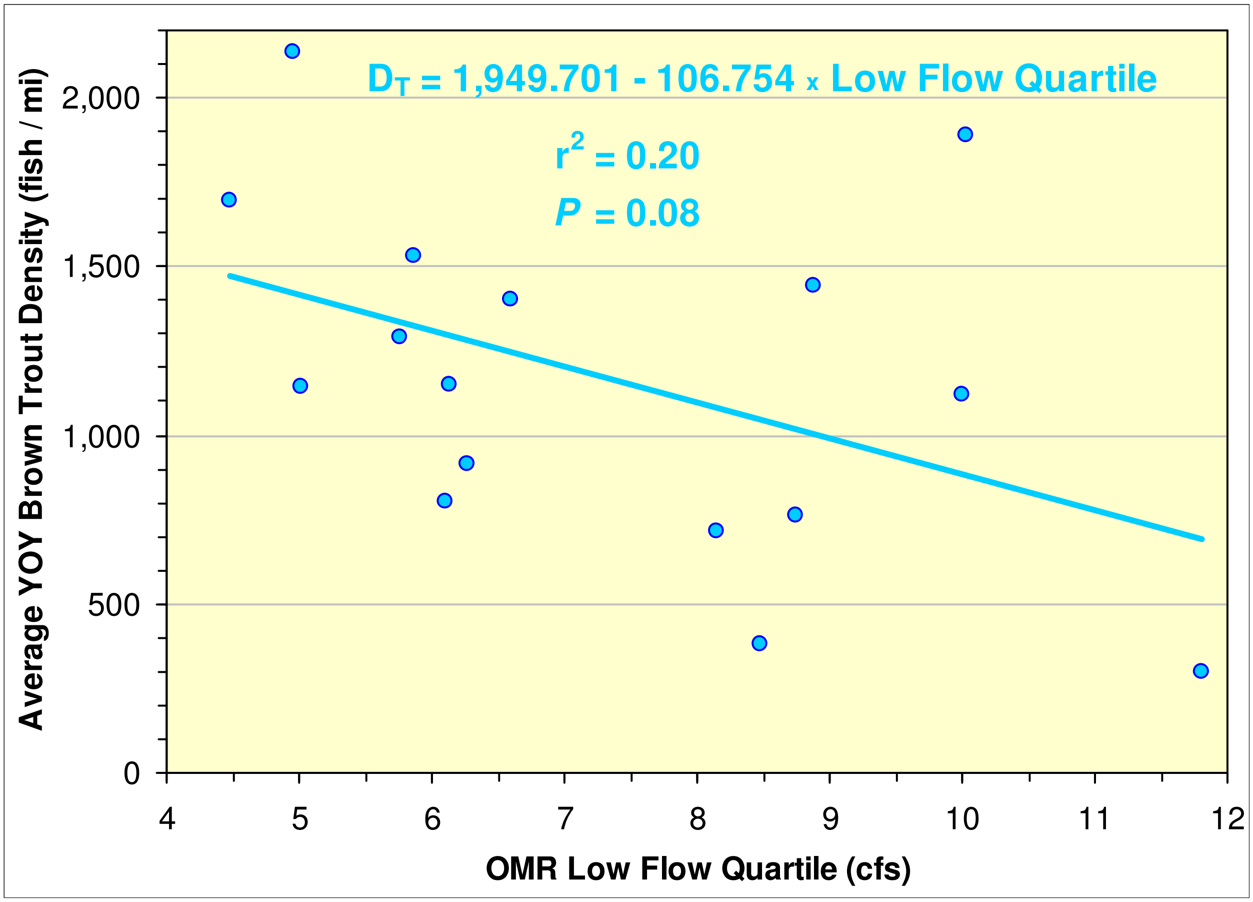

Figure 14. Annual Mammoth Creek average YOY brown trout density as function of OMR Low Flow Quartile and corresponding fitted linear regression line for the period 1988 through 2007.

6.0 DISCUSSION

California Fish and Game Code (Sections 5937 and 5946) stipulates that the owner of a dam is required to allow sufficient water to pass the dam in order to keep fish in the stream below the dam in good condition[3]. Mammoth Community Water District is obligated to meet this requirement. The term "good condition" although not well defined, implies a variety of biotic and abiotic factors that influence the aquatic community. CDFG's testimony before the State Water Resources Control Board regarding the maintenance of fish in good condition and stream flow requirements in streams tributary to Mono Lake was as follows:

> *"[t]he instream flows necessary to keep fish in good condition include those which will maintain a self-sustaining population of desirably-sized adult vertebrate fish which are in good physical condition i.e. well proportioned, and*

[3] The term "fish" as defined in California Fish and Game Code Sections 5937 and 5946 includes both vertebrate and invertebrate aquatic life.

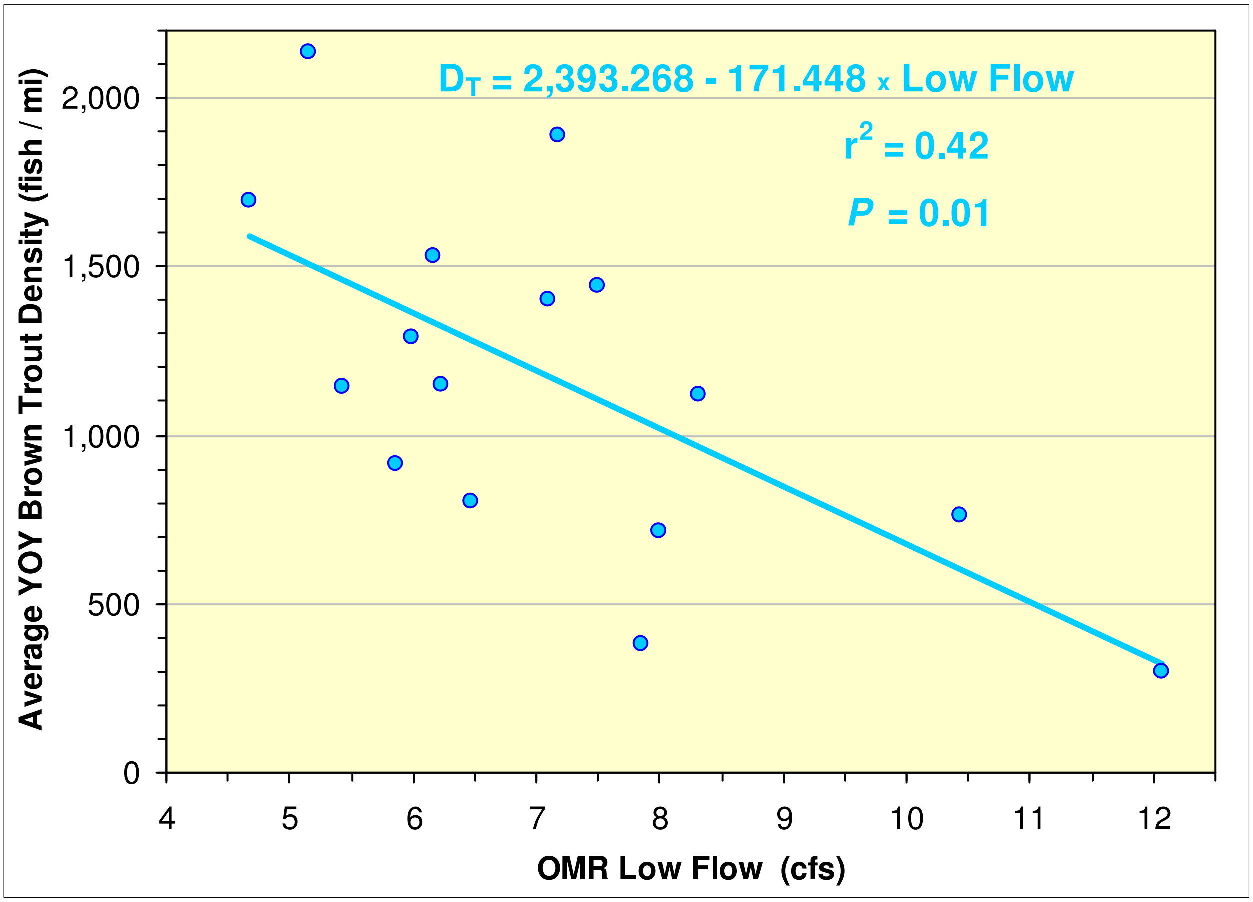

Figure 15. Annual Mammoth Creek average YOY brown trout density as function of OMR Low Flow and corresponding fitted linear regression line for the period 1988 through 2007.

disease-free. Fish populations should not be limited by lack of cover, food availability, poor water quality (including temperature), or lack of habitat necessary for reproduction. The fish populations should contain good numbers of different age classes, and habitat for these life stages should not be limiting.

Therefore, the "good condition" requirement must include the protection and maintenance of the physical, geological, and chemical parameters that constitute the ecology of the stream. The ecological health of the stream will determine if fish, both vertebrates and invertebrates, are to be kept in good condition."[4]

[4] Taken from CDFG testimony at SWRCB hearings for Mono Lake and the Mono Basin in September 1990 (from CH2M Hill 2000).

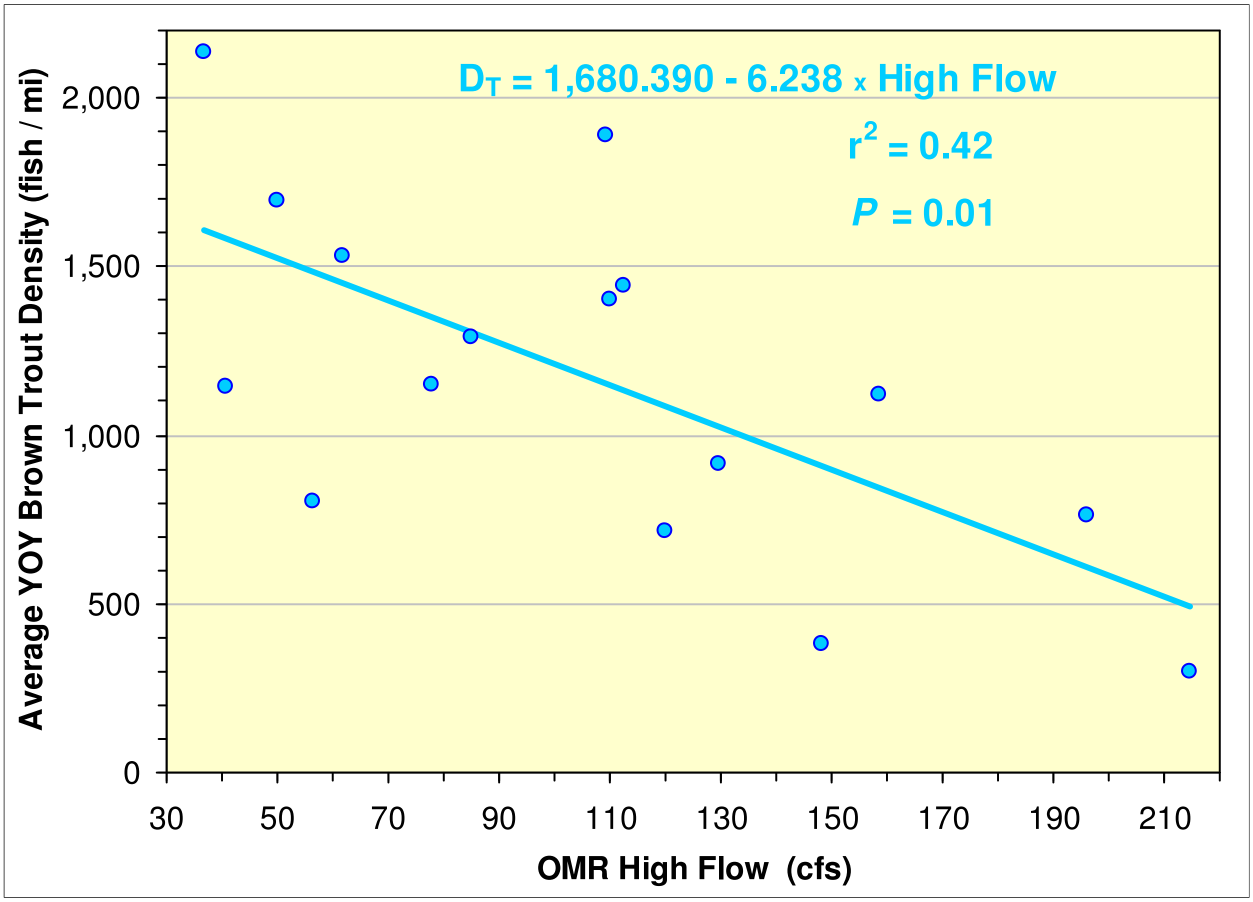

Figure 16. Annual Mammoth Creek average YOY brown trout density as function of OMR High Flow and corresponding fitted linear regression line for the period 1988 through 2007.

As discussed in CH2M Hill (2000), CDFG's definition focuses on the ecological heath of the stream as the indicator of good condition, and identifies the factors that indicate ecological health. These factors include: (1) attributes of the fish population such as a self-sustaining population with multiple age classes and appropriate abundance, in good physical condition; and (2) various stream characteristics including availability of food, cover, habitat, suitable water quality conditions, and the maintenance of these conditions. This definition also specifies that invertebrates as well as vertebrate fish are to be maintained in good condition (CH2M Hill 2000).

6.1 ABUNDANCE

Data obtained over the 16 years of fish community survey surveys in Mammoth Creek demonstrate considerable variation in trout abundance among years, and among sample sites within years. Variation in trout abundance is most likely in response to variable environmental conditions (e.g., stream flows, water temperature, habitat availability and suitability), variable biologic responses (e.g., reproductive success, over-winter survival, food availability, growth,

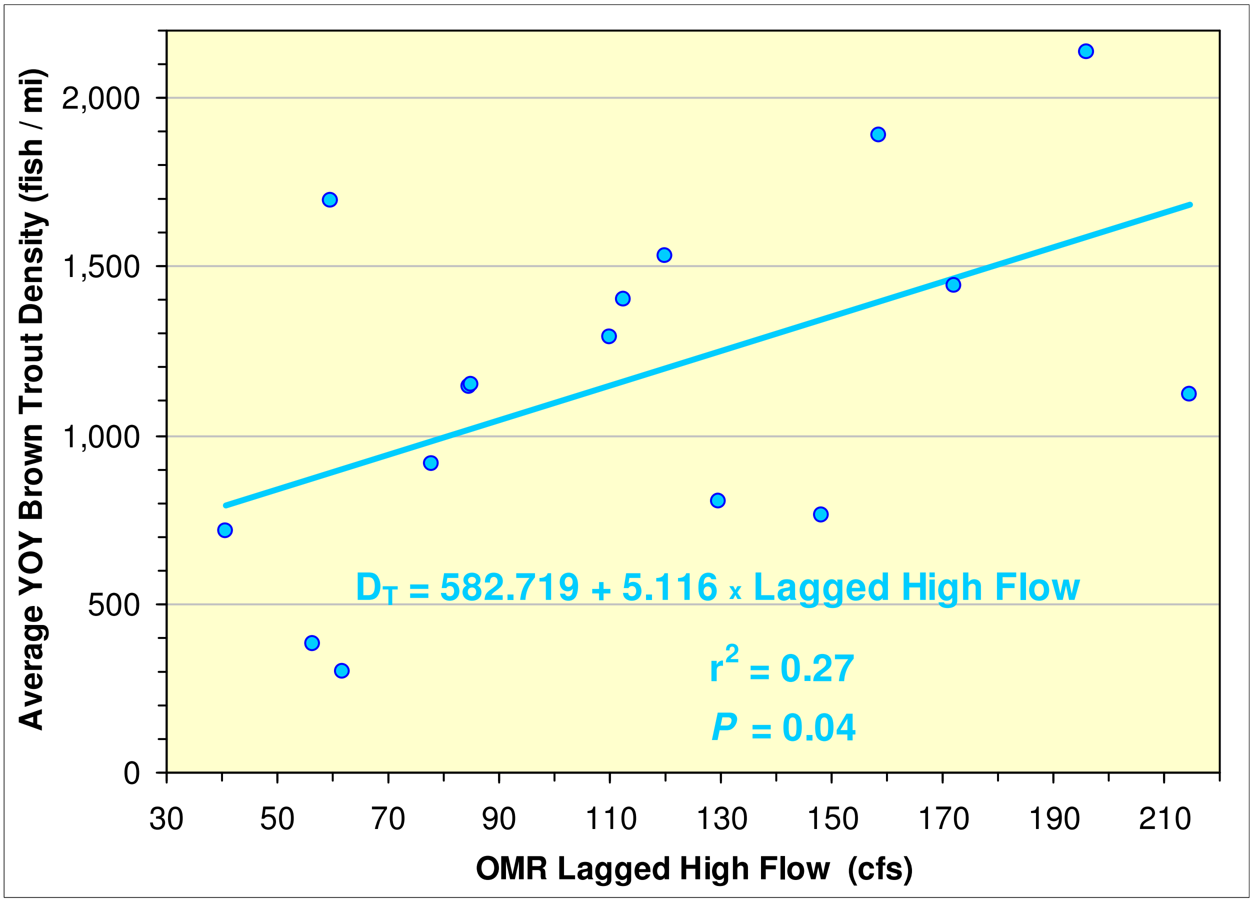

Figure 17. Annual Mammoth Creek average YOY brown trout density as function of one-year-lagged OMR High Flow and corresponding fitted linear regression line for the period 1988 through 2007.

year-class strength and recruitment potential), and variable anthropogenic influences (e.g., hatchery stocking practices, recreational angling, land use and development).

Insight to the recent status of trout abundance in Mammoth Creek can be gained by comparison to estimates of abundance in nearby creeks during the 1970s and 1980s, prior to development in the Mammoth Lakes Basin (particularly in the Town of Mammoth Lakes) and the increased recreational use that has occurred over about the last three decades.

Although the overall lack of complete and accurate measurement of fish weights and sample site areas prohibit the accurate calculation of area-based biomass (i.e., fish pounds per acre) for previous survey years, Salamunovich (2006) reported biomass estimates for the 2006 fish survey. He reported that seven of the eight sample sites in Mammoth Creek range from 11-20 feet in width, and provided an average wild trout (both brown and rainbow) biomass estimate of 92.9 pounds per acre, and ranged from a low of 46.5 pounds per acre at site CL to a high of 156.5 pounds per acre at site DH. These biomass estimates exceed the approximate 33 to 35 pounds per acre for similarly-sized Sierra streams reported by Gerstung (1973). The eighth sample site

(BL) in Mammoth Creek was characterized by a mean width of less than 10 feet, and provided a wild trout biomass estimate of 70 pounds per acre during 2006 (Salamunovich 2006).

CDFG conducted a survey of fish populations in streams of the Owens River drainage in 1983 and 1984 (Deinstadt *et al.* 1985). Fish populations were estimated within preselected sampling sections and then, based upon the length of each individual sampling section, directly extrapolated and expressed as the number of trout per mile. In creeks near Mammoth Creek, CDFG estimated from 877 to 4,822 brown trout per mile in four sections of Convict Creek, and from 600 to 1,109 brown trout per mile in McGee Creek. In addition to nearby creeks, CDFG also estimated brown trout abundance in Mammoth Creek itself. CDFG's estimates for five sections of Mammoth Creek ranged from 493 to 2,798 brown trout per mile. By comparison, although subject to inter-annual variability, annual average abundance of brown trout at individual sample sites ranges from 553 brown trout per mile at sample site CL to 4,165 brown trout per mile at sample site BH, with an overall average of 1,580 per mile for the 16-year period of record. These comparisons indicate that brown trout abundance in recent years is comparable to abundance estimates from over 20 years ago in nearby creeks, as well as from Mammoth Creek itself.

Rainbow trout also exhibit inter- and intra-annual (among site) variability in abundance in Mammoth Creek, and are much less abundant than brown trout. Examination of the data suggests that "wild" rainbow trout abundance (fish/mile) is somewhat cyclic over the 16-year period of record, with generally distinguishable 4-5 year cycles when "wild" rainbow trout abundance fluctuates about the long-term (16-year) average. "Wild" rainbow trout abundance increased from 2004 through 2006, and decreased in 2007. As previously mentioned, however, "wild" rainbow trout data must be interpreted with caution because of the problems associated with the identification of "wild" versus hatchery rainbow trout, the unaccounted for variations in hatchery planting practices, and recreational angling harvest.

6.2 RESILIENCE

Population resilience (i.e., the ability of the population to recover from episodic environmental events that reduce population numbers) also is an important indicator of the condition of the population and the quality of the habitat (CH2M Hill 2000). Fish populations with relatively high reproductive potential and that inhabit streams where spawning habitat is not limiting can recover quickly from short-term reductions in numbers and maintain a relatively stable long-term population. By contrast, populations with low reproductive potential or that occupy streams where spawning habitat, or habitat for early life stages is limiting, may remain depressed for longer periods following isolated events that reduce population numbers (CH2M Hill 2000).

For the 16 years of fish survey data, the brown trout abundance indicators of annual average abundance (number per mile) and YOY density (number/mile) for Mammoth Creek exhibit considerable inter-annual variation. Examination of the data demonstrates that the brown trout population has the ability to recover (i.e., exhibit increased abundance) relatively quickly following episodic reduced abundance levels in specific years. For example, the lowest abundance among all 16 years of sampling for all brown trout, as well as for YOY brown trout, occurred in 1995. However, by 1997 the second highest abundance of brown trout (and YOY brown trout) occurred, over a four-fold increase over 1995 levels. The second-lowest year of brown trout abundance occurred in 2005, yet the abundance of all brown trout and of YOY brown trout increased substantially in 2006, and in 2007 achieved over a four-fold increase of 2005 levels, for the highest annual abundance of all 16 years. These trends indicate the resiliency of the brown trout populations in Mammoth Creek.

6.3 SIZE/AGE STRUCTURE

Examination of brown trout length-frequencies demonstrates that multiple size/age classes were generally present during each of the 16 annual fish surveys in Mammoth Creek. From the data included in Figure 3, it is evident that the YOY size class dominates the brown trout populations in each reach of Mammoth Creek. Overall, the YOY size class comprised approximately 71% of all brown trout captured over the 16 years of sampling in Mammoth Creek.

The largest group each year most likely represents YOY fish from 50 to 120 mm in fork length (FL), the group from about 120 to about 180 mm FL probably represents Age I fish, the group from about 180 to 260 mm FL are most likely Age II fish, and fish in the 260 to 320 mm FL size range may represent Age III fish. Older fish may be represented by the few fish captured that were larger than 320 mm (up to 462 mm) FL.

Although ages of fish were not directly estimated from these studies, the length groups observed correspond well with previous investigations. Average length at annulus formation for brown trout in east slope Sierra Nevada streams has been reported to range from 84-139 mm FL (Age I) 160-257 mm FL (Age II), and 252-318 mm FL (Age III) (Snider and Linden 1981). In nearby Hot Creek, the average length at annulus formation was reported to range from 133-157 mm FL (Age I), 227-243 mm FL (Age II), and 291-317 mm FL (Age III) (Snider and Linden 1981).

Available data demonstrate that Mammoth Creek supports a self-sustaining population of brown trout of multiple size/age classes, including adult-sized fish.

6.4 PHYSICAL CONDITION

The previously described CDFG interpretation of "good condition" included fish in good physical condition (i.e., well-proportioned and disease-free). Over the 16 years of fish community surveys in Mammoth Creek, general reporting of visual examination of fish for external indicators of disease or fish "health" (i.e., lesions, tumors, parasites) is lacking. However, physical condition in terms of physiologic proportion, expressed as Fulton's Condition Factor (K), is reported for the first and last two survey years. The condition factor compares an individual fish's weight-length relationship, with values of 1.0 or more generally considered normal for a healthy trout population (Salamunovich 2006).

For the earliest (1988) survey, 93 percent of all brown trout collected exhibited condition factors equal to or exceeding a value of 1.0. For the 2006 survey, reported condition factors for both brown and "wild" rainbow trout at all sampling sites were well above the 1.0 "healthy" trout level (Salamunovich 2006), while for the 2007 survey, 97 percent of all brown trout and "wild" rainbow trout collected exhibited condition factors equal to or exceeding a value of 1.0. Thus, available information indicates that resident trout, particularly brown trout, in Mammoth Creek are in good physical condition.

6.5 HABITAT

Habitat considerations also were included in CDFG's interpretation of good condition – specifically, that fish populations should not be limited by lack of cover, poor water quality (including water temperature), or lack of habitat necessary for reproduction.

Fish cover can be characterized as instream cover including factors such as surface water turbulence, instream object cover (hydraulic roughness elements generally in the form of large substrates or woody material), undercut banks, aquatic vegetation, and overhanging vegetation proximate to the water surface. Fish cover also can be characterized as riparian vegetation and its associated canopy cover. Although the dominant cover type varies among sample sites, all of the sample sites contain some forms of instream cover (Salamunovich 2006). With the exception of the lowest reach (Reach E), which is in active pastureland, Mammoth Creek supports riparian communities (CH2M Hill 2006). As previously discussed, anecdotal observations suggest that riparian cover may have increased at certain sample sites since 1988 through the establishment of willows.

Available water temperature information for Mammoth Creek is presented in CH2M Hill (2006), and this brief summary of water temperature considerations is taken directly from that report. Water temperature data collected during 1988 and 1989 at various locations indicate that water temperature in Mammoth Creek fluctuates daily, with the magnitude of the fluctuation dependent upon location and time of year. Daily temperature fluctuations were lowest in the upstream sections of the creek (about 5 to 9^{o}F at Sherwin Street) and greatest in Reach E (about 16 to 23 ^{o}F). The maximum daily fluctuations occurred during the summer months; daily fluctuations were nearly nonexistent during the winter months when water temperature during the entire winter period was near 32 ^{o}F. Maximum daily temperature also varied by location and time of year. The highest maximum daily water temperatures occurred in the downstream sections (Reaches D and E) during the summer, with temperatures of about 68 ^{o}F recorded on occasion.

Mammoth Community Water District collected additional water temperature data in 1992 from two locations: near the Old Highway 395 crossing (Reach D); and near the confluence with Hot Creek (Reach E in Chance Meadow). These temperature records provided results similar to those found in 1988. The highest maximum daily water temperatures occurred during the summer, with temperatures of about 68 ^{o}F recorded on occasion near Old Highway 395 and temperatures near 79 ^{o}F occasionally recorded in Chance Meadow.

As reported by CH2M Hill (2000), water temperatures recorded during 1988 and 1989 were generally within the optimal ranges reported for fry, juvenile, and adult life stages of brown trout during the summer, and were less than optimal but generally within the tolerance range during fall and spring. Water temperatures during winter were generally at or slightly below the reported tolerance range for all life stages. High water temperatures do not appear to be a significant problem in Mammoth Creek. For example, the upper limiting, near lethal water temperature for adult brown trout was reported at 27.2^{o}C, or about 81 ^{o}F (Needham 1969 *as cited in* CH2M Hill 2006). At this temperature, naturally reproducing, viable stream populations would not be maintained (Raleigh *et al.* 1986; Needham 1969 *as cited in* CH2M Hill 2006).

Review of the information presented in CH2M Hill (2000) also suggests that maximum daily water temperatures in the lowermost section of Mammoth Creek near its confluence with Hot Creek can reach stressful levels during the summer, although those temperatures are present only for relatively short periods due to the substantial diurnal fluctuations.

Finally, it is clear that habitat necessary for reproduction is not lacking in Mammoth Creek. The dominance of YOY trout each year of the 16 annual surveys demonstrates successful reproduction.

Available information therefore indicates that the trout populations in Mammoth Creek, particularly the brown trout populations, are not limited by lack of cover, poor water quality (including water temperature) or lack of habitat necessary for reproduction.

6.6 MACROINVERTEBRATES/FISH FOOD AVAILABILITY

The previously described CDFG interpretation of maintaining "good condition" addresses the macroinvertebrate community, and the term "fish" as defined in California Fish and Game Code Sections 5937 and 5946 includes both vertebrate and invertebrate aquatic life. A thorough examination and discussion of available benthic macroinvertebrate community information for Mammoth Creek is presented in Appendix A. Following is a brief summary of that information.

CH2M Hill (2000) reported that the aquatic invertebrate sampling conducted from 1992 to 1994 suggests that the aquatic invertebrate community is relatively healthy, being composed of a relatively large number of taxa (around 20), representing a number of different families (around 15), and with good representation of the more sensitive taxa within the EPT orders. Standard diversity measures indicate that the ecological health of the benthic invertebrate fauna did not change significantly between 1992 and 1994 (Vinson 1995 *in* CH2M Hill 2000).

Subsequent BMI sampling was conducted as a requirement of the Hot Creek Hatchery NPDES permit. Sampling was conducted at one Mammoth Creek site upstream of the confluence with Hot Creek and at multiple sites in Hot Creek from 2000 through 2004. Two additional sites on Mammoth Creek were sampled during 2004 only.

Examination of individual metrics from all years provides variable results. Specifically, some metrics indicate that Mammoth Creek has better conditions than Hot Creek in general, while others indicate better conditions in Hot Creek. Additionally, some metrics display high degrees of spatial and/or temporal variability, while others are consistent among years and sites. However, a statistical examination of the data indicate that four of the twelve metrics examined strongly support ($p<0.05$) the hypothesis that Hot Creek below the confluence with Mammoth Creek has lower biotic integrity than Mammoth Creek, while two give the opposite result and the other six metrics differ by too little or are too variable to provide evidence one way or the other. Six of twelve metrics strongly support the hypothesis that the Hot Creek Hatchery springbrook inflows have lower biotic integrity than Mammoth Creek. Metrics varied in both directions between Hot Creek above and below the confluence with Mammoth Creek. However, twice as many metrics indicate an increase in biotic integrity below the confluence with Mammoth Creek (Jellison *et al.* 2005a).

A multi-metric evaluation of data obtained from 2004 sampling events indicated that biotic integrity in Mammoth Creek is better than that of Hot Creek below the hatchery (i.e., upstream of Mammoth Creek) and is similar to Hot Creek below the confluence with Mammoth Creek. However, because the multi- metric analysis was performed using data from only one year, the results should be interpreted carefully. Specifically, the high degree of variability in many of the individual metrics utilized in the multi-metric analysis could affect the overall multi-metric index score at any individual site, thereby potentially skewing the results of the analysis.

Overall, analysis of available data indicates that, over time and among sites, Mammoth Creek benthic macroinvertebrates are in comparatively good condition.

6.7 POPULATION TEMPORAL TRENDS/FLOW CONSIDERATIONS

Of all of the various indices of abundance examined for the 16 years of fish survey data, YOY brown trout density is the most reliable indicator of the annual status of trout populations in Mammoth Creek because it is not directly influenced by the planting of hatchery fish, or by recreational angling.

As previously presented, what appears to be a very slight trend of declining YOY brown trout abundance over the 16 years of fish survey data is not significant. Moreover, a very slight but non-significant decreasing temporal trend in the annual average YOY brown trout densities for the entire (all reaches) Mammoth Creek study area also is evident in recent years (1999-2007). Recent years are characterized by a "wet" hydrologic period. In fact, over the 16 years included in the analysis, three of the five highest peak spring/early summer runoff flows (expressed as OMR High Flow) have occurred during the last five years, although 2007 was a dry year with the second lowest peak spring/early summer runoff flows in the 16-year study period (OMR High Flow = 36.7 cfs).

As previously discussed, over the 16 years of fish community surveys, brown trout populations have exhibited sporadic years of reduced abundance. CH2M Hill (2000) attributes the episodic occurrences of low brown trout abundance to the influence of high runoff years that result in low population densities the following autumn. In the 1999 Fish Community Survey Report, Dr. Thomas Jenkins came to a similar conclusion, stating …

> *"Brown and rainbow trout populations are undergoing natural variations in population density, almost certainly in synchrony with other snow-melt dominated Easter Sierra streams. If minimum flows are not decreased beyond what has occurred in census years (e.g., to the point of exposing spawning gravels), and if the stream is not physically altered, we expect that the future trajectory of Mammoth Creek trout populations will depend primarily on the negative relationship between high stream flows and survival of juvenile trout."*

The analyses of the 16 years of Mammoth Creek fish survey data support these previous conclusions. Evaluation of the data demonstrates that YOY brown trout density is significantly associated with flow during the summer/autumn low-flow period in Mammoth Creek. In fact, the statistically significant trend in the data suggest that annual average YOY brown trout density is <u>negatively</u> associated with flow during the summer/autumn low-flow period (i.e., higher YOY brown trout density is associated with lower flow). This relationship may actually reflect the dominant influence of antecedent spring/early summer peak runoff flows on the establishment of brown trout initial year-class strength in Mammoth Creek. A highly significant, although moderately weak, negative relationship is evident between annual average YOY brown trout density and spring/early summer peak runoff flows (i.e., the higher the peak runoff flow, the lower the YOY brown trout density the following autumn).

The relationships between annual average YOY brown trout density and flow during the summer/autumn low-flow period should not be interpreted to mean that flows during summer and autumn are not important for juvenile rearing trout, or that flow-related habitat availability does not provide the opportunity for the establishment of relatively abundant initial year-classes of trout in Mammoth Creek. Rather, the available data from 1988-2007 most probably reflect the negative influence of spring/early summer peak runoff flows on the number of YOY brown trout present each year to utilize available summer/autumn rearing habitat in Mammoth Creek.

Finally, as previously presented, results indicate that due to the relatively high densities of YOY brown trout in Reach B, combined with the weak to moderate, and moderately significant decreasing linear trend in recent YOY brown trout density in Reach B, the overall slight declining linear trend in YOY brown trout density in Mammoth Creek during recent years (1999-2007) is mostly influenced by Reach B. Also, a weak to moderate, and highly significant negative relationship is evident between annual average YOY brown trout density for the entire creek and spring/early summer peak runoff flows (i.e., the higher the peak runoff flow, the lower the YOY brown trout density the following autumn). However, further examination of the data reveals that annual average YOY brown trout density in Reach B (individually) is not significantly associated (r^2 = 0.13, P = 0.18) with spring/early summer peak runoff flow (expressed as OMR High Flow), whereas moderately weak (r^2 = 0.23, 0.37 and 0.33) and significant ($P<0.06$) were found for reaches C, D and E, respectively. This conflicting trend in Reach B, relative to the entire Mammoth Creek, suggests that some other factor or factors contribute, at least partially, to the weak to moderate, and moderately significant declining linear trend in YOY brown trout density in Reach B during recent years. Potential contributing factors are uncertain, although it is noted that Reach B passes through the Town of Mammoth Lakes, where much of the local area development has occurred during recent years. A discussion of the development and activities that have occurred over the past decade within and along Reach B of Mammoth Creek is presented in **Appendix B**.

6.8 CONCLUSIONS

As previously discussed, CDFG's interpretation of maintenance of fish populations in good condition below a dam focuses on the ecological health of a stream, and identifies several components that contribute to ecological health, including fish population attributes and various stream habitat characteristics. The results of the analysis of 16 years of fish monitoring data in Mammoth Creek and available macroinvertebrate data indicate the following:

- Rainbow and brown trout annually persist in Mammoth Creek, and brown trout abundance is comparable to abundance estimates from 25 to 30 years ago in nearby creeks, as well as within Mammoth Creek itself;
- The brown trout population in Mammoth Creek is resilient and has the ability to recover from episodic environmental events that reduce population numbers;

- Mammoth Creek supports a self-sustaining population of brown trout comprised of multiple size/age classes, including adult-sized fish;
- Resident trout, particularly brown trout, in Mammoth Creek are in good physical condition;
- Habitat conditions in Mammoth Creek include sufficient cover, water quality, and habitat necessary for reproduction to maintain trout populations in good condition;
- Successful reproduction of trout in Mammoth Creek occurs each year;
- The macroinvertebrate community in Mammoth Creek is in comparatively good condition;
- YOY brown trout density, the most reliable indicator of the annual status of trout populations in Mammoth Creek, is significantly associated with flow during the summer/autumn low flow period. The relationships indicate that YOY brown trout densities decrease with increased flow during the summer/autumn low flow period. However, these relationships may actually reflect the dominant influence of antecedent spring/early summer peak runoff flows on the establishment of brown trout initial year-class strength;
- For Mammoth Creek overall, YOY brown trout density is negatively associated with spring/early summer peak runoff flows (i.e., high peak runoff flows result in low YOY brown trout densities); and
- The lack of a relationship between YOY brown trout densities in Reach B (individually) and flows suggests that other factors contribute, at least partially, to years of relatively low YOY brown trout densities in Reach B, the reach that passes through the Town of Mammoth Lakes.

In conclusion, consideration of all of the above fish population attributes and stream characteristics indicates that the trout population in Mammoth Creek is in good condition.

7.0 REFERENCES

Beak Consultants Incorporated. 1991. Brown Trout and Rainbow Trout Instream Flow Requirements in Mammoth Creek, California. Draft Report. Prepared for Mammoth Community Water District, Mammoth Lakes, California.

Bratovich, P.M., K.L. Carlson, D.B. Christophel, and T.A. Jackson. 1990. Mammoth Creek Instream Flow Investigations. Prepared by Beak Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

California Department of Water Resources. 1973. Mammoth Basin Water Resources Environmental Study. December 1973 Final Report.

CH2M Hill. 2000. Environmental Impact/Report/Environmental Impact Statement – Changes in Mammoth Creek Instream Flow Requirements, Change of Point of Measurement, and Change of Place of Use. Prepared for: Mammoth Community Water District and United States Forest Service.

Deinstadt, J.M., D.R. McEwan, and D.M. Wong. 1985. Survey of Fish Populations in Streams of the Owens River Drainage: 1983-84. California Department of Fish and Game, Inland Fisheries Administrative Report No. 85-2. Rancho Cordova, California.

Gerstung, E.R. 1973. Fish Population and Yield Estimates from California Trout Streams. Cal-Neva Wildlife 1973: 9-19.

Hankin, D.G. 1984. Multistage Sampling Designs in Fisheries Research: Applications in Small Streams. J. Fish. Aquat. Sci., 41: 1575-1591.

Hankin, D.G. 1986. Sampling Designs for Estimating the Total Number of Fish in Small Streams. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, PNW-360, Portland, Oregon.

Hood, D.J. 1998. Mammoth Creek 1997 Fish Community Survey. Prepared by KDH Biological Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

Hood, D.J. 2001. Mammoth Creek 2000 Fish Community Survey. Prepared by KDH Biological Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

Hood, D.J. 2002. Mammoth Creek 2001 Fish Community Survey. Prepared by KDH Biological Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

Hood, D.J. 2003. Mammoth Creek 2002 Fish Community Survey. Prepared by KDH Biological Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

Hood, D.J. 2004. Mammoth Creek 2003 Fish Community Survey. Prepared by KDH Biological Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

Hood, D.J. 2006a. Mammoth Creek 2004 Fish Community Survey. Prepared by KDH Biological Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

Hood, D.J. 2006b. Mammoth Creek 2005 Fish Community Survey. Draft report prepared by KDH Biological Consultants for the Mammoth Community Water District, Mammoth Lakes, California.

Hood, D.J., P.M. Bratovich, and D.B. Christophel. 1993. Mammoth Creek 1993 Fish Community Survey. Prepared by Beak Consultants for the Mammoth County Water District, Mammoth Lakes, California.

Hood, D.J., P.M. Bratovich, and D.B. Christophel. 1994. Mammoth Creek 1994 Fish Community Survey. Prepared by Beak Consultants for the Mammoth County Water District, Mammoth Lakes, California.

Hood, D.J., D.B. Christophel, and P.M. Bratovich. 1992. Mammoth Creek Fish Community Survey. Prepared by Beak Consultants for the Mammoth County Water District, Mammoth Lakes, California.

Jenkins, T.M., Jr. 1999. Mammoth Creek 1999 Fish Community Survey. Prepared by Horseshoe Canyon Biological Consultants for the Mammoth County Water District, Mammoth Lakes, California.

Jenkins, T.M., Jr., and D.R. Dawson. 1996. Mammoth Creek 1995 Fish Community Survey. Prepared by Sierra Nevada Aquatic Research Laboratory for Mammoth County Water District, Mammoth Lakes, California.

Jenkins, T.M., Jr., and D.R. Dawson. 1997. Mammoth Creek 1996 Fish Community Survey. Prepared by Sierra Nevada Aquatic Research Laboratory for Mammoth County Water District, Mammoth Lakes, California.

Jenkins, T.M., Jr., S. Diehl, K. Kratz, and S.D. Cooper. 1999. Effects of Population Density on Individual Growth of Brown Trout in Streams. Ecology 80:941-956.

Moyle, P.B. 2002. Inland Fishes of California, 2nd Edition. University of California Press, Berkeley, California. 502p.

Moyle, P.B., R.M. Yoshiyama, and R.A. Knapp. 1996. Status of Fish and Fisheries. Chapter 33 in Sierra Nevada Ecosystem Project Final report to Congress, Volume II, Assessments and scientific basis for management options. University of California Centers for Water and Wildland Resources, Davis, CA.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout, Revised. U.S. Fish and Wildlife Service Biological Report 82(10.124). 65pp.

Salamunovich, T. 2006. October 2006 Mammoth Creek Fish Community Survey. Prepared by Thomas R. Payne & Associates for the Mammoth Community Water District, Mammoth Lakes, California.

Salamunovich, T. 2007. Mammoth Creek Fish Community Survey, Unpublished Data. Prepared by Thomas R. Payne & Associates for the Mammoth Community Water District, Mammoth Lakes, California.

Skalski, J.R. and D.S. Robson. 1992. Techniques for Wildlife Investigations, Design and Analysis of Capture Data. Academic Press, Inc., San Diego, CA, 237 p.

Snider, W.M. and A. Linden. 1981. Trout Growth in California Streams. California Department of Fish and Game, Inland Fisheries Administrative Report No. 81-1. Sacramento, California.

Van Deventer, J.S. and W.S. Platts 1986. User’s guide for Microfish 2.3. A Software Package for Processing Electrofishing Data Obtained by the Removal Method. Forestry Sciences Laboratory, Boise, Idaho.

Van Deventer, J.S., and W.S. Platts. 1989. Microcomputer Software System for Generating Population Statistics from Electrofishing Data - User's Guide for MicroFish 3.0. USDA, Forest Service General Technical Report INT-254. Intermountain Research Station, Ogden, Utah. 29p.

White, G.C., D.R. Anderson, K.P. Burnham and D.L. Otis 1982. Capture-Recapture and Removal Methods for Sampling Closed Populations. Los Alamos National Laboratory Report, LA-8787NERP: 235 p.

Zippin, C. 1956. An Evaluation of the Removal Method of Estimating Animal Populations. Biometrics, 12: 163-169.

Zippin, C. 1958. The Removal Method of Population Estimation. J. Wildlife Management, 22: 82-90.